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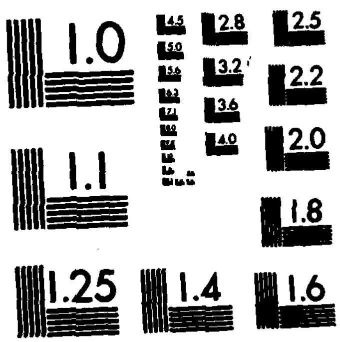

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INTEGRATED AERODYNAMIC TESTS OF THE SPACE SHUTTLE VEHICLE DURING SOLID ROCKET BOOSTER SEPARATION AT MACH 4.5 (IA193)

W. A. Crosby and D. L. Lanham,
Calspan Field Services, Inc.

June 1982

Final Report for Period March 9 through 31, 1982

Approved for public release; distribution unlimited.

ARNOLD ENGINEERING DEVELOPMENT CENTER
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APPROVAL STATEMENT

This report has been reviewed and approved.

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Deputy for Operations

Approved for publication:

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Static force and moment tests were conducted in the VKF Tunnel A using the captive trajectory system to simulate solid rocket booster (SRB) separation maneuvers from the space shuttle orbiter/external tank at Mach 4.5. Phase I test objectives were to determine proximity interference aerodynamics of the SRBs with the booster separation motors active. The Phase II effort developed an expanded aerodynamic data base, up to longitudinal separation distances of 1700 in., with a single SRB and no motor modeling. Limited testing was accomplished at Mach 4.0 to determine Mach number effect. These tests are identified by NASA as IA193.

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CONTENTS

APPENDIXES

NOMENCLATURE

A	Reference area, 38.736 in.^{2}
A_n	Thrust tare curve fit coefficient
ALP-BL, ALP-BR	SRB angle of attack, left and right SRB, deg
ALPHAC	CTS pitch drive, deg
ALP-OT	O + ET angle of attack, deg
ALP-T	CTS model angle of attack, deg
BETA-BL, BETA-BR	SRB sideslip angle, left and right SRB, deg
BETA-OT	O + ET sideslip angle, deg
BETA-T	CTS model sideslip angle, deg
BSM	Booster Separation Motor
CATOT	O + ET total axial-force coefficient, total axial force/Q8•A
CLLOT	O + ET rolling-moment coefficient, rolling moment/Q8•A•L
CLNOT	O + ET yawing-moment coefficient, yawing moment/Q8•A•L
CLNL, CLNR	SRB aero yawing-moment coefficient, left and right SRB, CLNTL - (MZJL/Q8•A•L) or CLNTR - (MZJR/Q8•A•L)
CLNTL,CLNTR	SRB total yawing-moment coefficient from both aerodynamic and thrust loads, left and right SRB, yawing moment/Q8•A•L
CMOT	O + ET pitching-moment coefficient, pitching moment/Q8•A•L
CML, CMR	SRB aero pitching-moment coefficient, left and right SRB, CMTL-(MYJL/Q8•A•L) or CMTR-(MYJR/Q8•A•L)

CMTL, CMTR	SRB total pitching-moment coefficient from both aerodynamic and thrust loads, left and right SRB, pitching moment/Q8•A•L
CNOT	0 + ET normal-force coefficient, normal force/Q8•A
CNL, CNR	SRB aero normal-force coefficient, left and right SRB, CNTL-(FNJL/Q8•A) or CNTR-(FNJR/Q8•A)
CNTL, CNTR	SRB total normal-force coefficient from both aerodynamic and thrust loads, left and right SRB, normal force/Q8•A
CODE	Configuration code number
CONFIG	Model configuration designation
CYOT	0 + ET side-force coefficient, side force/Q8•A
CYL, CYR	SRB aero side-force coefficient, left and right SRB, CYTL-(FYJL/Q8•A) or CYTR-(FYJR/Q8•A)
CYTL, CYTR	SRB total side-force coefficient from both aerodynamic and thrust loads, left and right SRB, side-force/Q8•A
DATA TYPE	Test matrix identifier
DELA	Aileron deflection angle, deg
DEL-AL, DEL-AR	Relative angle of attack between O + ET and SRB, (ALP-BL)-(ALP-OT) or (ALP-BR)-(ALP-OT), deg
DELBF	Body flap deflection angle, deg
DEL-BL, DEL-BR	Relative sideslip angle between 0 + ET and SRB, (BETA-BL)-(BETA-OT) or (BETA-BR)-(BETA-OT), deg
DELE	Elevon deflection angle, deg
DEL-P	Venturi mass flow meter differential pressure, psia
DEL-PL, DEL-PR	Relative roll angle between 0 + ET and SRB, (PHI-BL)-(PHI-OT) or (PHI-BR)-(PHI-OT), deg

DELR	Rudder deflection angle, deg
DELSB	Speed brake deflection angle, deg
DEL-XL, DEL-XR	Relative longitudinal separation distance of SRB nose from mated position, positive aft, in.
DEL-YL, DEL-YR	Relative lateral separation distance of SRB nose from mated position, positive nose right from pilot's point of view, in.
DEL-ZL, DEL-ZR	Relative vertical separation distance of SRB nose from mated position, positive nose down from pilot's point of view, in.
ETAC	CTS aft yaw drive, deg
FNJL, FNJR	SRB thrust normal force, left and right SRB, $A_0 + A_1(PSL)$ or $A_8 + A_9(PSR)$, lbs
FYJL, FYJR	SRB thrust side force, left and right SRB, $A_4 + A_5(PSL)$ or $A_{12} + A_{13}(PSR)$, lbs
GRID	A predetermined set of model positions used to command the CTS model motion in computer control
L	Model reference length, 12.903 in.
LTAFT, RTAFT	Aft balance temperature for left and right SRB, respectively, °F
LTFW, RTFW	Forward balance temperature for left and right SRB, respectively, °F
MACH	Free stream Mach number
MDOTV	Computed venturi mass-flow meter mass flow, lbm-sec^{-1}
MTL, MTR	Computed BSM mass flow for left and right SRB, respectively, lbm-sec^{-1}
MYJL, MYJR	SRB thrust pitching-moment, left and right SRB, $A_2 + A_3(PSL)$ or $A_{10} + A_{11}(PSR)$, in.-lbf

MZJL, MZJR	SRB thrust yawing moment, left and right SRB, $A_6 + A_7$(PSL) or $A_{14} + A_{15}$ (PSR), in.-lbs
O + ET	Integrated orbiter/external tank configuration
PA	Supply pressure of the venturi mass flow meter, psia
PB1, PB2	Orbiter base pressure, psia
PC	Orbiter balance cavity pressure, psia
PCHAL, PCHAR	Chamber pressures for aft BSM on left and right SRB, respectively, psia
PCHFL, PCHFR	Chamber pressures for forward BSM on left and right SRB, respectively, psia
PHI-BL, PHI-BR	SRB roll angle, left and right SRB, deg
PHICB	CTS roll drive, deg
PHI-OT	O + ET roll angle, deg
PHI-T	CTS model roll angle, deg
PN	Data point number
PO	Tunnel stilling chamber pressure, psia
PSL, PSR	Pressure in sting mass flow supply to BSM on left and right SRB, respectively, psia
PSWB	Tunnel sidewall static pressure at Station 47.5, psia
PSWT	Tunnel sidewall static pressure at Station 75.0, psia
P8	Free-stream static pressure, psia
Q8	Free-stream dynamic pressure, psia
RE/FT	Free-stream unit Reynolds number, ft^{-1}

REL	Free-stream Reynolds number based on orbiter model length (12.903 in.)
RUN	Data set identification number
SRB	Solid rocket booster
TA	Supply temperature of venturi mass flow meter, °R
TDP	Dew point temperature of the air in the high pressure bottle used to supply the BSM jet simulation, °F
TO	Tunnel stilling chamber temperature, °R
T8	Free-stream static temperature, °R
X	CTS model axial position, in.
XC	CTS axial drive, in.
Y	CTS model lateral position, in.
YAWC	CTS forward yaw drive, deg
YPOT1, YPOT2	Potentiometer readings of the forward and aft drive motors on the SRB strut assembly (Phase I only), in.
Z	CTS model vertical position, in.
ZC	CTS vertical drive, in.

MODEL CONFIGURATION DESIGNATION

The following nomenclature was used to designate the model components in the test summaries and the data package.

O(Orbiter) = $B_{62}C_{12}E_{44}F_{10}M_{16}N_{89}N_{103}R_5V_8W_{116}$

where

SYMBOL	COMPONENT DESCRIPTION
B_{62}	Body
C_{12}	Canopy
E_{44}	Elevon
F_{10}	Body Flap
M_{16}	OMS pod
N_{89}	MPS Nozzles
N_{103}	OMS nozzles
R_5	Rudder
V_8	Vertical tail
W_{116}	Wing

ET(External Tank) = $T_{35}AT_{28}AT_{130}AT_{131}FL_{10}FL_{11}FR_{10}FR_{14}FR_{15}FR_{16}FR_{17}$

$FR_{18}FR_{19}PT_{23}PT_{25}PT_{26}PT_{29}PT_{33}PT_{39}$

where

SYMBOL	COMPONENT DESCRIPTION
T_{35}	Modified vehicle 5 ET
AT_{28}	Aft orbiter/ET attach structure
AT_{130}	Forward orbiter/ET attach structure
AT_{131}	Aft orbiter/ET attach structure cross-member
FL_{10}	LH_2 Feedline
FL_{11}	LO_2 Feedline
FR_{10}	Fairing

SYMBOL	COMPONENT DESCRIPTION
FR_{14}	ET nose cable fairing
FR_{15}	ET nose fairing for PT_{39}
FR_{16}	LO_2 feedline (FL_{11}) Fairing
FR_{17}	LO_2 anti-geyser line (PT_{23}) fairing
FR_{18}	Aft electrical conduit (PT_{25}) fairing
FR_{19}	LH_2 pressure line (PT_{33}) fairing
PT_{23}	LO_2 recirculation line
PT_{25}	Aft electrical line
PT_{26}	LO_2 pressure line
PT_{29}	Electrical conduit
PT_{33}	LH_2 pressure line
PT_{39}	ET nose probe

$$\text{SRB(Solid Rocket Booster)} = S_{24}N_{101}N_{102}N_{106}PS_{20}PS_{26}PS_{27}PS_{28}PS_{29}PS_{31}PS_{32}PS_{33}PS_{34}PS_{35}$$

where

SYMBOL	COMPONENT DESCRIPTION
S_{24}	Modified vehicle 5 SRB
N_{101}	Forward booster separation motor nozzle block
N_{102}	Aft booster separation motor nozzle block
N_{106}	SRB nozzle
PS_{20}	Electrical cable tunnel
PS_{26}	SRB aft attach ring
PS_{27}	Separation motor nozzle actuator struts
PS_{28}	Aft booster separation motor fairing

SYMBOL	COMPONENT DESCRIPTION
PS_{29}	Tiedown struts (4)
PS_{31}	Command antennae (2)
PS_{32}	Data capsule camera
PS_{33}	Intermediate structural rings (3)
PS_{34}	Aft cable housing
PS_{35}	Aft structural ring

1.0 INTRODUCTION

The work reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 921E01, Control Number 9E01, at the request of NASA/Johnson Space Center, Houston, TX 77058 for the Rockwell International (RI) Space Systems Group, Downey, CA 90241. The NASA project manager was M. K. Craig and the RI project engineers were H. S. Dresser, J. W. McClymonds, R. H. Spangler, and R. P. Clark. The results were obtained by Calspan Field Services, Inc./AEDC Division, operating contractor for the Aerospace Flight Dynamics testing effort at the AEDC, AFSC, Arnold Air Force Station, Tennessee. The tests were conducted in the von Karman Gas Dynamics Facility (VKF) supersonic Tunnel A during the period of 9-31 March 1982 under AEDC Project Number C696VA (Calspan Project Number V41A-1G).

The primary test objectives were to obtain proximity interference aerodynamics of the Space Shuttle Vehicle Orbiter/External Tank (O + ET) and Solid Rocket Boosters (SRB) during separation maneuvers both with and without the influence of the SRB's booster separation motors (BSM), refine the separation aerodynamic uncertainties during vehicle staging, and expand the BSM jet-off data base. Visual documentation at selected test conditions and attitudes of the BSM plume interaction was recorded using the tunnel schlieren system.

The test program was accomplished in a two phase effort. Phase I testing utilized a dual SRB installation with active BSM simulation at various jet to free-stream pressure ratios. Other test variables included O + ET angle of attack (-10 to +10 deg), O + ET sideslip (0 to +10 deg), SRB angle of attack (-17 to +10 deg), SRB sideslip angle (-17 to +10 deg), and SRB roll angle (0 and 3 deg). The staging process was simulated by moving the O + ET model away from the SRB's using the tunnel's 6 DOF Captive Trajectory System (CTS). The full-scale separation varied longitudinally from 0 to 200 in., laterally 0 to 150 in., and vertically from 0 to 280 in. The start point for all positioning sequences was the mated position, which is defined to be the launch configuration. Six-component force and moment data on the O + ET and 4-component force and moment data on each SRB were obtained.

The Phase II entry, designed to expand the BSM plume-off data base, also utilized the positioning flexibility of the CTS to locate a single SRB (right) relative to the O + ET configuration. The full-scale separation variables included longitudinal distances from 0 to 1700 in. with lateral and vertical separation of 0 to 800 in. and 0 to 1000 in., respectively. SRB angle of attack (-44 to +10 deg) and sideslip angle (-30 to +18 deg) were also varied. The entire matrix was repeated at selected O + ET angle of attack and sideslip angle combinations from -10 to +10 deg. Mated position again served as the starting point for the grid sequences. Six-component force and moment data on the O + ET and 4-component force and moment data on the SRB were obtained.

Typically the data were obtained in a hypercube test matrix format. Hypercubes are a data management technique whereby discrete test data points are selected to represent the boundaries of nominal and off-nominal trajectory paths. The trajectory paths are identified in multi-dimensional space (the number of dimensions is equivalent to the number of test variables) of which the corners, when projected in a 2D plane, represent the required data points that give the best linear interpolation during execution of off-line trajectory programs. The use of hypercubes avoids obtaining voluminous and often unnecessary test data. In addition, trajectory and isolated vehicle test matrices were completed for both phases, as well as an asymmetry matrix (i.e., asymmetry between SRB and O + ET arrangement) in Phase I. An asymmetry matrix was not required for the Phase II entry as the installation was asymmetric by definition. All testing was accomplished at Mach 4.5 and free-stream unit Reynolds number of 1.5-million/ft. The trajectory matrix was also run at Mach 4.0 and free-stream unit Reynolds number of 1.3-million/ft.

The tests complement similar entries designated IA40, IA142, and IA143 conducted in Tunnel A during 1976.

All test data have been transmitted to the Rockwell International Space Systems Group and NASA/JSC as described in Table 1. Inquiries to obtain copies of the test data should be directed to NASA/Johnson Space Center, EX43, Houston, TX 77058. Only a microfilm record has been retained in the VKF at AEDC.

2.0 APPARATUS

2.1 TEST FACILITY

Tunnel A (Fig. 1) is a continuous, closed-circuit, variable density wind tunnel with an automatically driven flexible-plate-type nozzle and a 40- by 40-in. test section. The tunnel can be operated at Mach numbers from 1.5 to 6 at maximum stagnation pressures from 29 to 200 psia, respectively, and stagnation temperatures up to 750°R at Mach number 6. Minimum operating pressures range from about one-tenth to one-twentieth of the maximum at each Mach number. The tunnel is equipped with a model injection system which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnel and airflow calibration information may be found in the Test Facilities Handbook (Ref. 1).

2.2 TEST ARTICLES

The test articles were 0.01-scale stainless steel and aluminum models of the space shuttle vehicle (designated model 75/72 OTS) orbiter, external tank, and solid rocket boosters. The orbiter body was the 140C modified configuration with the 140 A/B wing. The external tank was built to the VC78-000002C lines and the solid rocket boosters were built to the VC77-000002 specifications. Model configuration designations are provided in the nomenclature. Component guidelines are included in Ref. 2. Model details are shown in Fig. 2, and Fig. 3 gives a three-view drawing of the integrated vehicle.

Model configuration components remained constant throughout the tests, except for the SRB separation motor thrust vector which was manually offset 3-deg more inboard during part of the Phase I trajectory runs. Nominal 20-deg BSM thrust vector outboard of the vertical centerline was common for all other test data. Orbiter control surface deflections were set at zero for these tests. All aerodynamically relevant surface protrusions and penetrations were simulated except for the SRB attach structure to the ET.

The booster separation motors consisted of four-nozzle clusters at the extreme forward and aft ends of each SRB. Full-scale dimensions were maintained except where it was necessary to provide nozzle contour changes for proper plume simulation and sufficient wall thickness to fabricate the nozzles. The model BSM nozzle geometry was based on pretest calibrations performed by RI during which the geometry (throat diameter, expansion angle) was adjusted to obtain the desired free-flight combination of plume shape, chamber pressure, and thrust. Air was supplied to each nozzle cluster through a common plenum. The model was constructed such that both forward and aft plenums operated at the same pressure.

The Phase I installation (see Fig. 4) included dual SRB's each mounted to a 4-component flow-through balance on a special support system (see Fig. 5) attached to the primary tunnel support. The RI fabricated SRB support rig combines manual and remote adjustments for model positioning. The support mechanism is capable of manual changes in pitch of each SRB independently from -25 to +25 deg in 1-deg increments (half-degree increments for odd numbered angles), as well as providing for yaw of the entire support assembly in 5-deg increments. Pinned position settings allow for vertical position changes also. Remote simultaneous lateral displacement and sideslip angle was accomplished by using two electric motors each driving a worm gear. Two offsets accommodating the SRB's balance-sting were designed and fabricated for this test to permit greater sideslip angle at close-in (small lateral displacement from mated position) separations than previously obtainable. The O + ET was mounted to a 6-component balance on the CTS.

Model inversion was required for the Phase II installation (see Fig. 6) since the single SRB (right) was mounted on the CTS. The O + ET model was mounted on a special single support mechanism attached to the primary tunnel support. This device allows for manual pitch clutch face changes of 0 to 25 deg in 5-deg increments while providing yaw angle adjustment for the entire rig in 5-deg increments, as well as vertical positioning at several pin settings. Vertical relocation of the support rig is required to keep the lower model in the same area of the test section and free from the influence of the tunnel boundary layer as the model pitch angle is changed. The same considerations for the CTS model, as well as the CTS drive limits, are included in determining the vertical shaft pinned position. The model/balance arrangements were the same as used in Phase I.

In both phases, base and balance cavity pressures were obtained on the orbiter model. The measurement locations are shown in Fig. 7.

2.3 TEST INSTRUMENTATION

A six component moment-type balance was used in the O + ET and four-component moment-type flow-thru balances were used in the SRB's. The O + ET was mounted to the Captive Trajectory System (CTS) in Phase I and the right SRB was mounted on CTS in Phase II. The CTS (Ref. 3) consists of a model support with electro-mechanical drive systems for six degrees of freedom and is attached to the top of Tunnel A as shown in the conceptual drawing given in Fig. 8. The axial and vertical motions (XC and ZC) are obtained using linear drive units while lateral motion is achieved by rotating the roll-pitch-yaw support arm about the vertical support arm at the vertical support axis with the aft yaw mechanism (ETAC) and compensating for the resulting yaw with the forward yaw mechanism (YAWC). The forward yaw and pitch (ALPHAC) motions are obtained through two kunckle joints with axes 90 deg to each other (the pitch axis is upstream of the yaw axis), and finally the most upstream motion of the system is the roll (PHICB). The excursion bands and rates of travel of the CTS drives are given in Table 2. The measuring devices, recording devices, calibration method, and estimated measurement uncertainties of the six degree of freedom motions of the CTS along with all other measured parameters are given in Table 3.

Remote positioning of the SRB's in the Phase I test was accomplished with a specially designed position controller. The controller incorporated existing tunnel pitch and roll system electronics with computer interface to position the two potentiometers of the SRB separation rig.

Model flow-field photographs were obtained using the Tunnel A double-pass optical flow visualization system. Color schlieren stills and movies (both high speed and low speed) were made at selected test conditions and model attitudes using this system. Video cassette recordings of the schlieren screen provided continuous documentation of the test.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS

A summary of the nominal test conditions at each Mach number is given below.

MACH	PO, psia	TO, °R	Q8, psia	P8, psia	RE/FT x 10^{-6}
4.5	23.5	590	1.15	0.081	1.5
4.0	15.7	590	1.15	0.102	1.3

Additional test data for BSM thrust calibrations were obtained with the tunnel evacuated as the initial and concluding runs of all Phase I test shifts.

At some test conditions, particularly at sub-atmospheric stagnation pressures, the air humidity level affects the test section Mach number. The Tunnel A sidewall Mach number probe is used periodically when testing at these conditions to monitor deviations from the standard calibrated Mach numbers. When a deviation is measured, the free-stream conditions are corrected and the actual Mach number is printed on the data tabulations.

Test summaries showing all configurations tested and the variables for each are presented in Table 4 (Phase I) and Table 5 (Phase II).

3.2 TEST PROCEDURES

3.2.1 General

For CTS tests in the continuous flow wind tunnels (A, B, C), the parent lower model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. The tank is separated from the tunnel by a pair of fairing doors and a safety door. When closed, the fairing doors, except for a slot for the pitch sector, cover the opening to the tank and the safety door seals the tunnel from the tank area. After the parent model is prepared for a data run, the personnel access door to the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, the model is injected into the airstream using the short inject stroke, and the fairing doors are closed. The short inject stroke is used to keep the sector out of the airstream. This reduces the possibility of tunnel blockage and also provides for more maneuverability of the CTS by reducing mechanical interference. The models are positioned and the data obtained. After this, the sequence is reversed and the tank is vented to atmosphere to allow access to the model in preparation for the next data set. The sequence is repeated for each configuration change. CTS model configuration changes require a tunnel shutdown to gain access to the model since the CTS cannot be retracted from the airstream. CTS model configurations remained constant for the tests.

CTS (upper) model attitude and positioning and data recording were accomplished using the CTS in the grid mode of operation. The grid matrices, which are tables of model attitude and position, were loaded into the DEC 10 computer prior to the test. During the test, the required grid was selected and the positioning of the model was controlled by the computer which automatically recorded all the data inputs at each grid point location. The process was repeated until the grid matrix was completed. The data recording for the parent model was accomplished using the tunnel data acquisition system which was also automatically controlled by the computer.

Initial alignment of the upper and lower models was provided by precision wind-off alignment using a docking spike and fixed target system. Aerodynamic deflection of the models and model support was assumed to be negligible.

Prior to initiating the Phase I test, two calibrations were performed. The first calibration provided BSM plenum chamber pressure correlation to SRB sting pressure levels. This was required as the chamber pressure tubing would affect balance measurements. Once the calibration was complete, the tubing was cut and crimped at the base of each SRB. During testing, sting pressures were set to achieve desired chamber pressure levels. The right SRB sting pressure was monitored for these set points. The chamber pressure levels were naturally balanced between the two SRB's without the use of throttling devices in each supply line. Sting pressure to BSM thrust components were also calibrated prior to test start. This was incorporated into the data reduction program to provide SRB forces and moments with and without the BSM thrust loads. As previously mentioned, the thrust calibration was repeated each test shift as a check on the balances and mass flow system. The Phase II test had no BSM simulation; thus these calibrations were not required.

During Phase I testing, the sequence of events is outlined in the following. The SRB's pitch and roll and the separation rig yaw and vertical positions were manually set to the desired locations. (SRB pitch angle was actually set 1.0 deg more positive than required to nominally compensate BSM thrust-induced deflection.) The CTS was then manually driven to position the O + ET for initial alignment. Once this was accomplished, CTS operation was switched to computer control for grid execution providing relative pitch, axial, and vertical separations. The SRB separation rig was used to set relative lateral positions and sideslip angles. This operation was also computer controlled utilizing the Model Attitude Control System (MACS) and control hardware specifically fabricated for this test. High pressure air supplied the BSM plenums through the Tunnel A auxiliary mass flow system. The SRB sting pressure was set automatically by a proportional integral derivative (PID) process controller. Once the BSM simulation parameters were set, the SRB's and then the O + ET were positioned. Vertical-plane deflection and displacement corrections were utilized to maintain required relative model locations. Horizontal-plane corrections were removed from the CTS drive equations in order to center the O + ET between the two SRB's and reduce asymmetry effects. This was done for each simulated BSM condition until all requirements for one manual setting of the SRB's and the separation rig were fulfilled. At this time, new settings were made and the procedure was repeated. Isolated O + ET data were obtained while model changes were in progress. It should be noted that parent model motion is typically not permitted, for safety considerations, when the CTS is located elsewhere than the stowed position. However, additional safety features were incorporated into the SRB position controller such that when model collisions did occur, the internal ground loop circuit was completed and all motor drive power was disengaged, thus preventing damage to the models. Extensive pretest checkout was performed to verify this circuitry.

BSM simulation at chamber pressures of 0 (DEL-XR=100, only), 900, 1200 (ALP-OT = BETA-OT = 0.0 deg), and 1500 psia was typical. At some relative model positions, however, a zone of instability existed where severe model vibration occurred, particularly at chamber pressures of 1500 psia. When this phenomenon presented itself, chamber pressures were immediately reduced to 1000 psia. Data were then obtained at every 100 psia increment until the onset of model vibration. For data at ALP-OT = BETA-OT = 10.0 deg and chamber pressure 1500 psia, tunnel blockage with associated loss of flow was encountered. The maximum allowable chamber pressure was reduced to 1300 psia for data at this attitude.

For Phase II testing, the required test procedures were significantly simpler. The 0 + ET was mounted on the lower model support where manual pitch and support rig yaw and vertical positions were set to desired attitudes. Again, the CTS was manually driven to position the SRB for initial alignment. Following transfer to computer control, the SRB was moved through pre-programmed grid sequences providing relative axial, vertical, lateral, pitch, and sideslip separations from the 0 + ET. This process was typical for each 0 + ET attitude. Isolated SRB data were obtained during model changes.

3.2.2 Data Acquisition

As described in Section 3.2.1, data were taken in the grid mode of operation using the CTS and tunnel data systems. The data were obtained at finite values of 0 + ET (Phase I) or SRB (Phase II) position and attitude. Each data point represents ten data samples averaged to obtain a single value. The ten samples obtained from the CTS and tunnel data systems were taken over a time span of 0.320 and 0.208 sec, respectively.

3.3 DATA REDUCTION

The model's static stability data were obtained utilizing the CTS and tunnel data acquisition systems as described in Section 3.2. The force and moment measurements were reduced to coefficient form using the averaged data points and correcting for first and second order balance interaction effects. Aerodynamic coefficients were also corrected for model tare weight, balance-sting deflections, and, where applicable, BSM thrust loads. Model attitude and tunnel stilling chamber pressure were also calculated from averaged values.

Model force and moment coefficients are presented in the body axis system. SRB pitching and yawing moment coefficients are referenced to a point on the model centerline which was 10.585 in. aft of the nose. 0 + ET moment reference point was located 0.500 in. above the ET's longitudinal centerline, 7.745 in. aft of the ET nose. Orbiter model body length (12.903 in.) and wing area (38.736 in.^{2}) were used as the reference length and area for all model force and moment coefficients.

During the pressure calibration, discussed in Section 3.2, the following correlations between sting and chamber pressures were obtained:

$$\text{PCHFR} = \text{PCHAR} = 0.9569 \cdot \text{PSR}$$

$$\text{PCHFL} = \text{PCHAL} = 0.9626 \cdot \text{PSL}$$

Thrust produced by BSM simulation was subtracted from SRB total balance loads to obtain the aerodynamic loads. The calibrations were evaluated from individual SRB data runs using a linear least-squares curve fit. Curve fit coefficients were determined for each thrust component for the two SRB's as a function of sting pressure. The nomenclature describes use of the curve fit coefficients (see below) for resolving thrust and aerodynamic loads from total measured balance loading.

	LEFT SRB			RIGHT SRB	
	PHI-BL=0.0	PHI-BL=3.0		PHI-BR=0.0	PHI-BR=-3.0
A_0	0.3584440	0.2083180	A_8	0.6973800	0.2030560
A_1	-0.0328247	-0.0321087	A_9	-0.0324081	-0.0315005
A_2	-0.3009130	-0.1272030	A_{10}	-0.7035660	-0.1996460
A_3	-0.0609367	-0.0594144	A_{11}	-0.0576084	-0.0560194
A_4	0.0482443	0.1542480	A_{12}	-0.2267810	-0.1577710
A_5	-0.0121350	-0.0139028	A_{13}	0.0123690	0.0141093
A_6	-0.0633086	0.6025380	A_{14}	-0.3263960	-0.2118560
A_7	-0.0231435	-0.0260361	A_{15}	0.0273331	0.0298395

Relative position between the O + ET and SRB(s) was given in full-scale vehicle inches. Figure 9 describes the sign convention for all separation parameters.

BSM mass flow was computed as a percentage of the supply system mass flow rate for each SRB ratioed to the left and right sting pressures.

3.4 UNCERTAINTY OF MEASUREMENTS

In general, instrumentation calibrations and data uncertainty estimates were made using methods recognized by the National Bureau of Standards (Ref. 4). Measurement uncertainty is a combination of bias and precision errors defined as:

$$U = \pm(B + t_{95}S)$$

where B is the bias limit, S is the sample standard deviation, and t_{95} is the 95th percentile point for the two-tailed Student's "t" distribution, (95-percent confidence interval) which for sample sizes greater than 30 is taken equal to 2.

Estimates of the data uncertainties in the basic measurements of this test are given in Table 3a. With the exception of the force and moment balance, data uncertainties are determined from in-place calibrations through the data recording system and data reduction program. Static load hangings on the balance simulate the range of loads and center-of-pressure locations anticipated during the test, and measurement errors are based on differences between applied loads and corresponding values calculated from the balance equations used in the data reduction. Load hangings to verify the balance calibration are made in place on the assembled model.

Propagation of the bias and precision errors of measured data through the calculated data are made in accordance with Ref. 6 and the results are given in Table 3b.

4.0 DATA PACKAGE PRESENTATION

The data package contains tabulated Orbiter/External Tank and SRB model aerodynamic force and moment data. Tabulated tunnel conditions, position, and BSM mass flow (Phase I) data are also included. The measured SRB model force and moment data from Phase I provides both total coefficients (aerodynamic and thrust) as well as aerodynamic coefficients. Sample tabulations are given in Appendix III. To facilitate comparison of IA193 test data with data from previous test entries, data run numbers were not duplicated. The data runs for IA193 were begun at Run 3000.

Data considered to be incorrect were deleted from the data package. Nonpertinent individual parameters within a run were suppressed from tabulation. For example, SRB aerodynamic and mass flow data were suppressed during isolated 0 + ET runs.

To aid sorting routines of NASA and RI for hypercube data, a grid numbering scheme was devised which identifies individual hypercube corners. An explanation of this technique is given in Table 6 and corresponds to all runs with data type equal 1 (HYPC, on tabulated data).

Other data types are categorized by the following, where the mnemonics on the tabulated data are given in parentheses, ( ) and the numeric categorization is supplied on the magnetic data tape. Trajectory data are designated data type 2 (TRAJ); Asymmetric, Phase I, runs are data type 3 (ASYM); isolated 0 + ET or SRB runs are data type 4 (ISOL); and data type 5 (MDOT) represents thrust calibrations.

Sample verification plots providing comparison of previous and present test data as well as hypercube data repeatability are given in Fig. 10.

REFERENCES

1. Test Facilities Handbook (Eleventh Edition). "von Karman Gas Dynamics Facility Vol. 3," Arnold Engineering Development Center, April 1981.

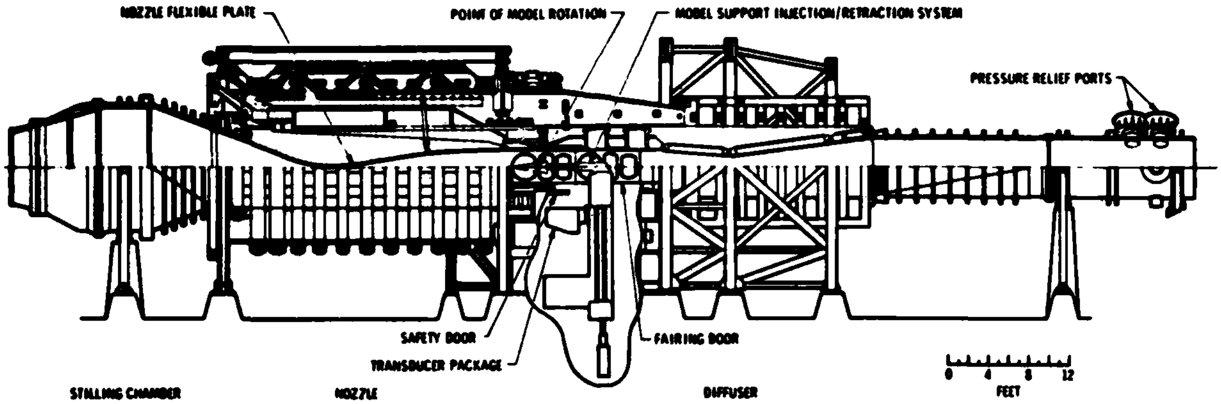
2. Clark, R. P. and Spangler, R. H. "Pretest Information of SRB Separation Test IA193 Using the 0.010-Scale SSV Model 75/72 OTS in the AEDC VKF Tunnel A." Rockwell International STS 81-0690, December 2, 1981.

3. Billingsley, J. P., Burt, R. H., and Best, J. T., Jr. "Store Separation Testing Techniques at the Arnold Engineering Development Center, Volume III: Description and Validation of Captive Trajectory Store Separation Testing in the von Karman Facility." AEDC-TR-79-1, March 1979.

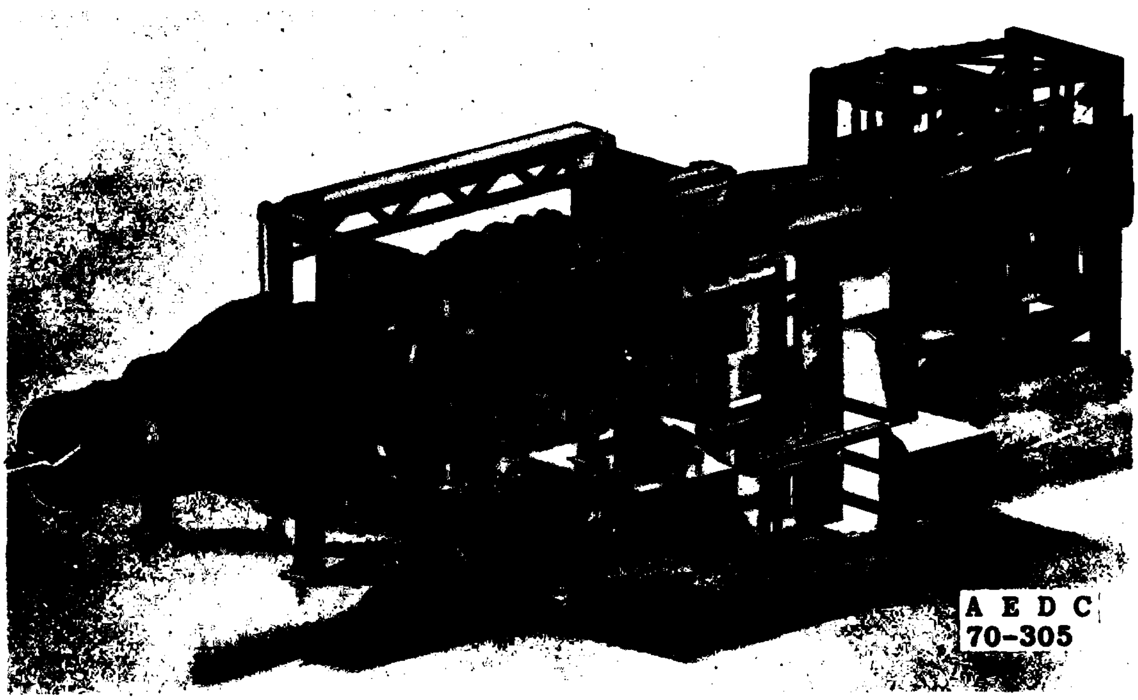
4. Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements," AEDC-TR-73-5 (AD-755356), February 1973.

APPENDIX I

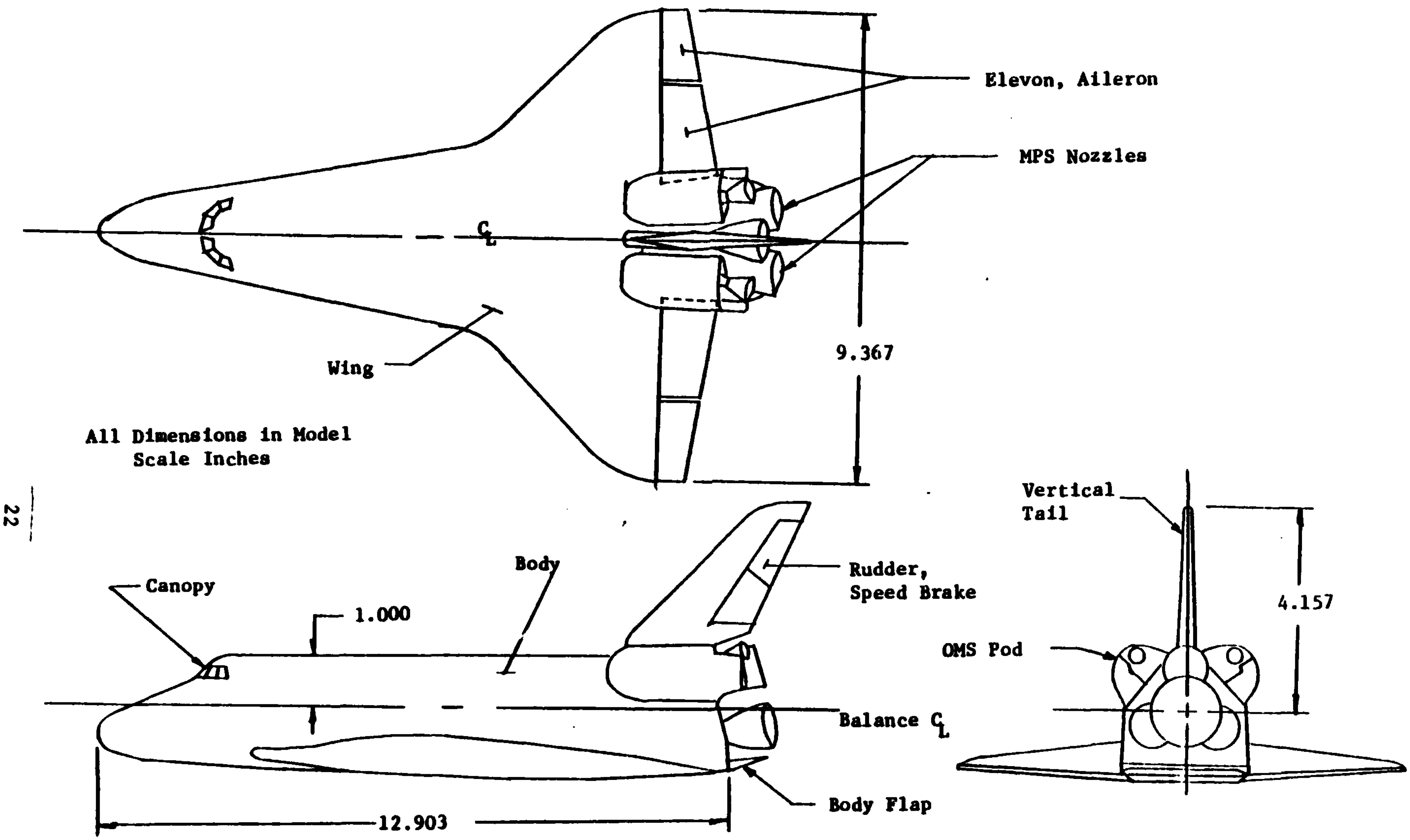
ILLUSTRATIONS



a. Tunnel assembly

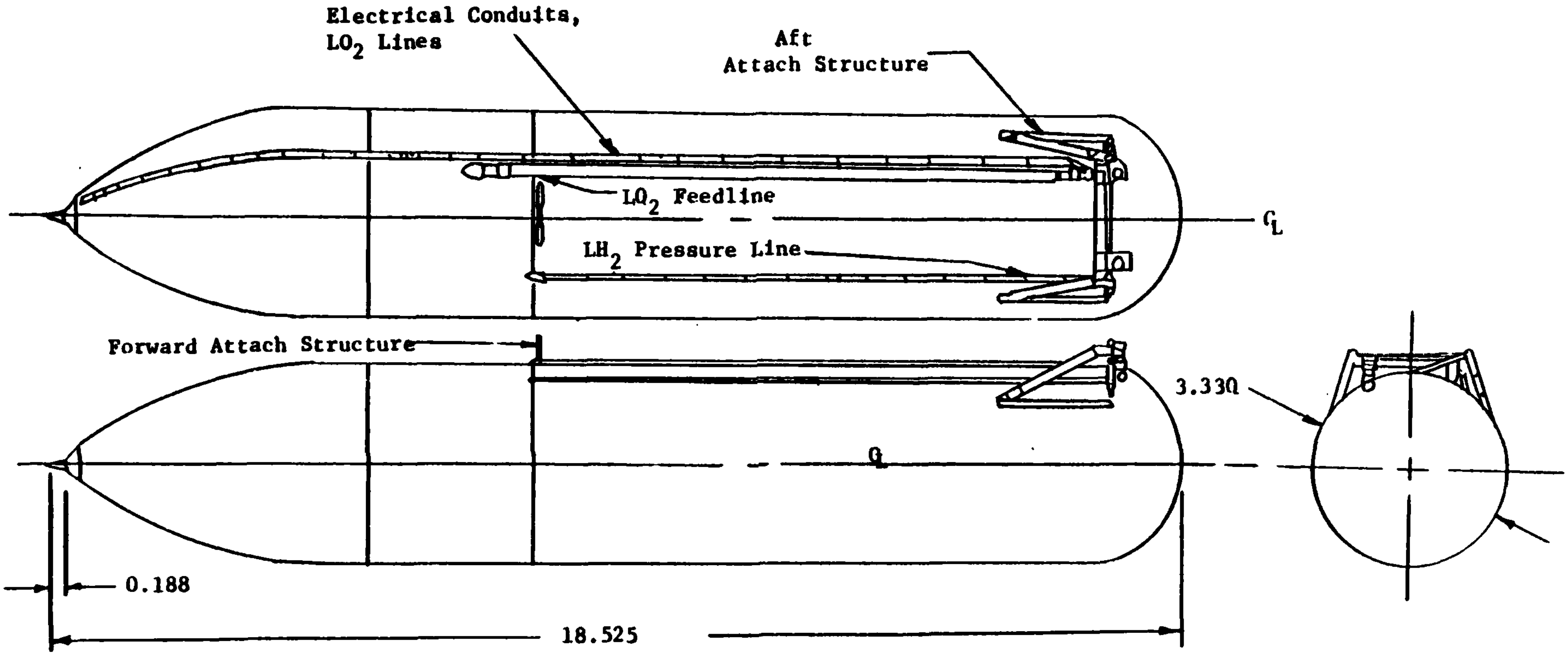


b. Tunnel test section
Fig. 1 Tunnel A



a. Orbiter

Figure 2. Model Details

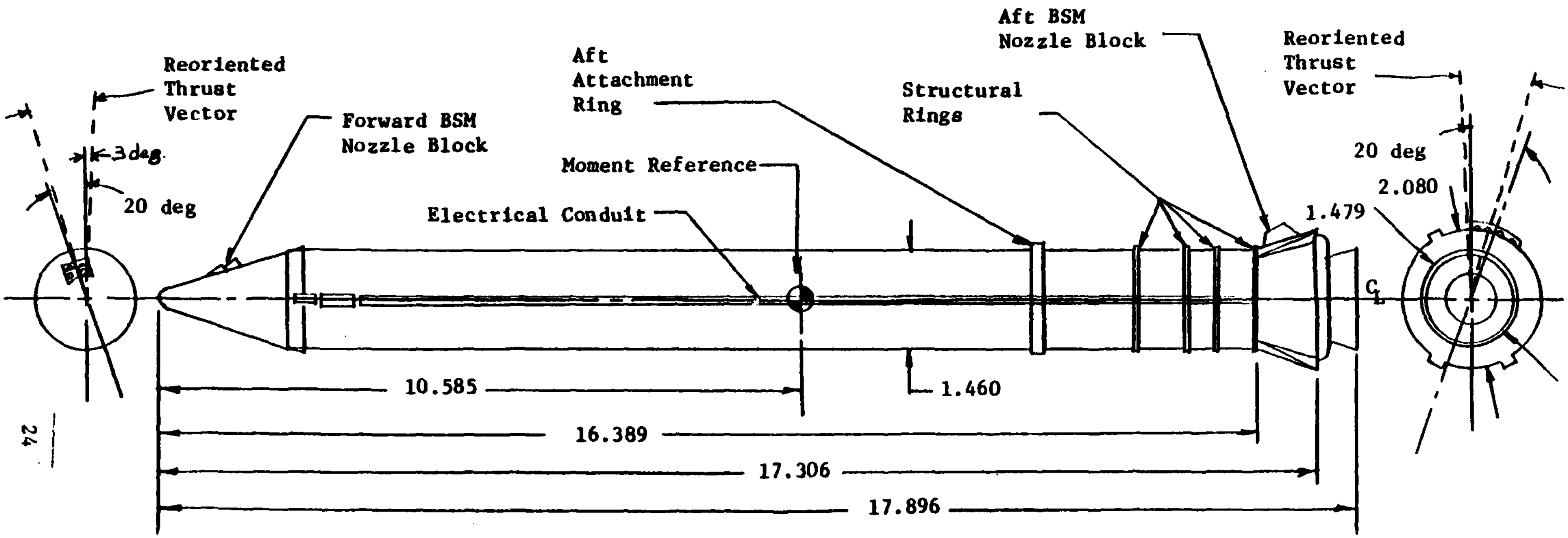


All Dimensions in Model
Scale Inches

b. External Tank

Figure 2. Continued

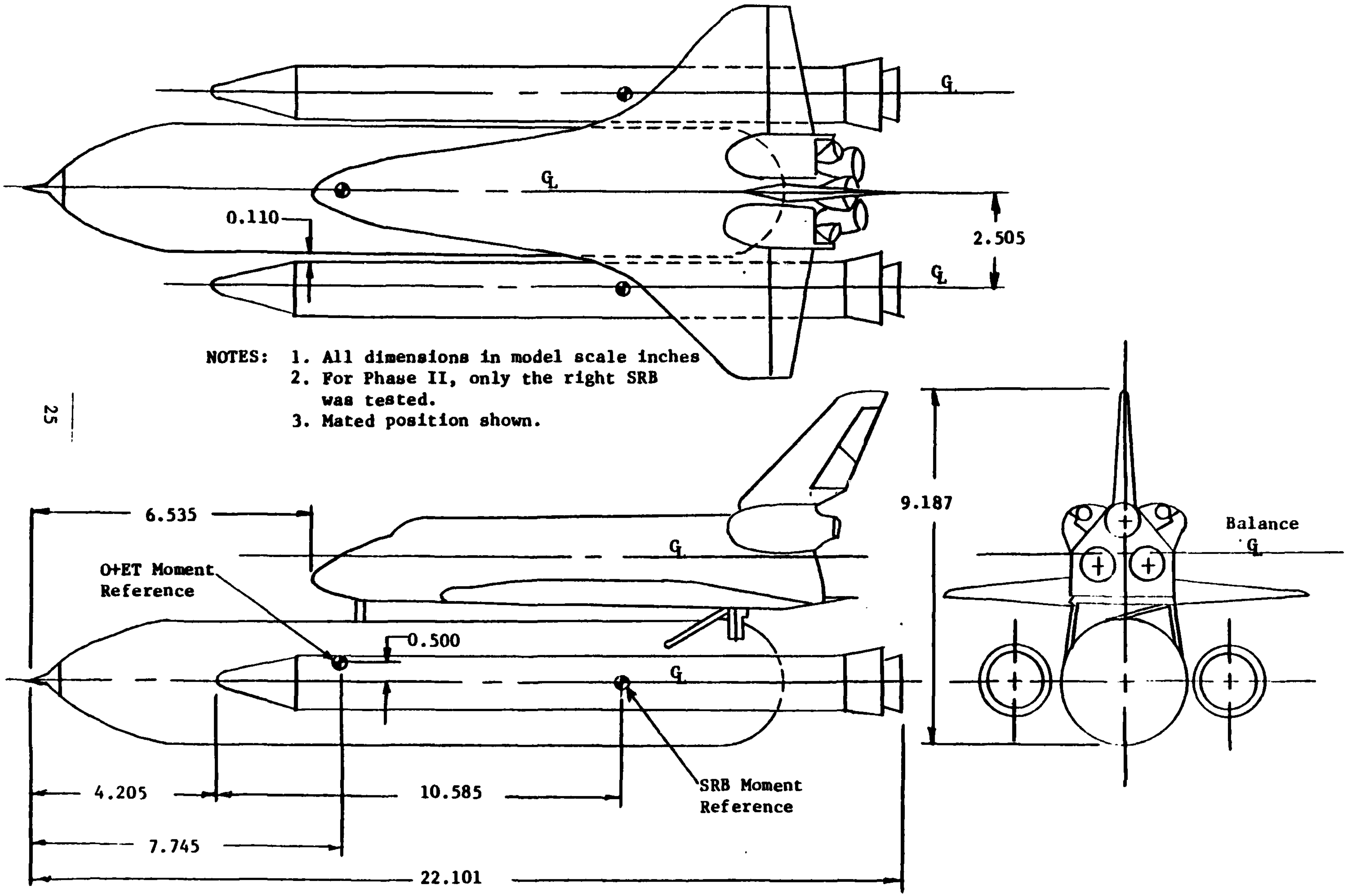
All Dimensions Given in
Model Scale Inches



Dimensions Typical for Both SRB's

c. Solid Rocket Booster

Figure 2. Concluded



NOTES: 1. All dimensions in model scale inches
2. For Phase II, only the right SRB was tested.
3. Mated position shown.

Figure 3. Integrated Space Shuttle Vehicle Configuration

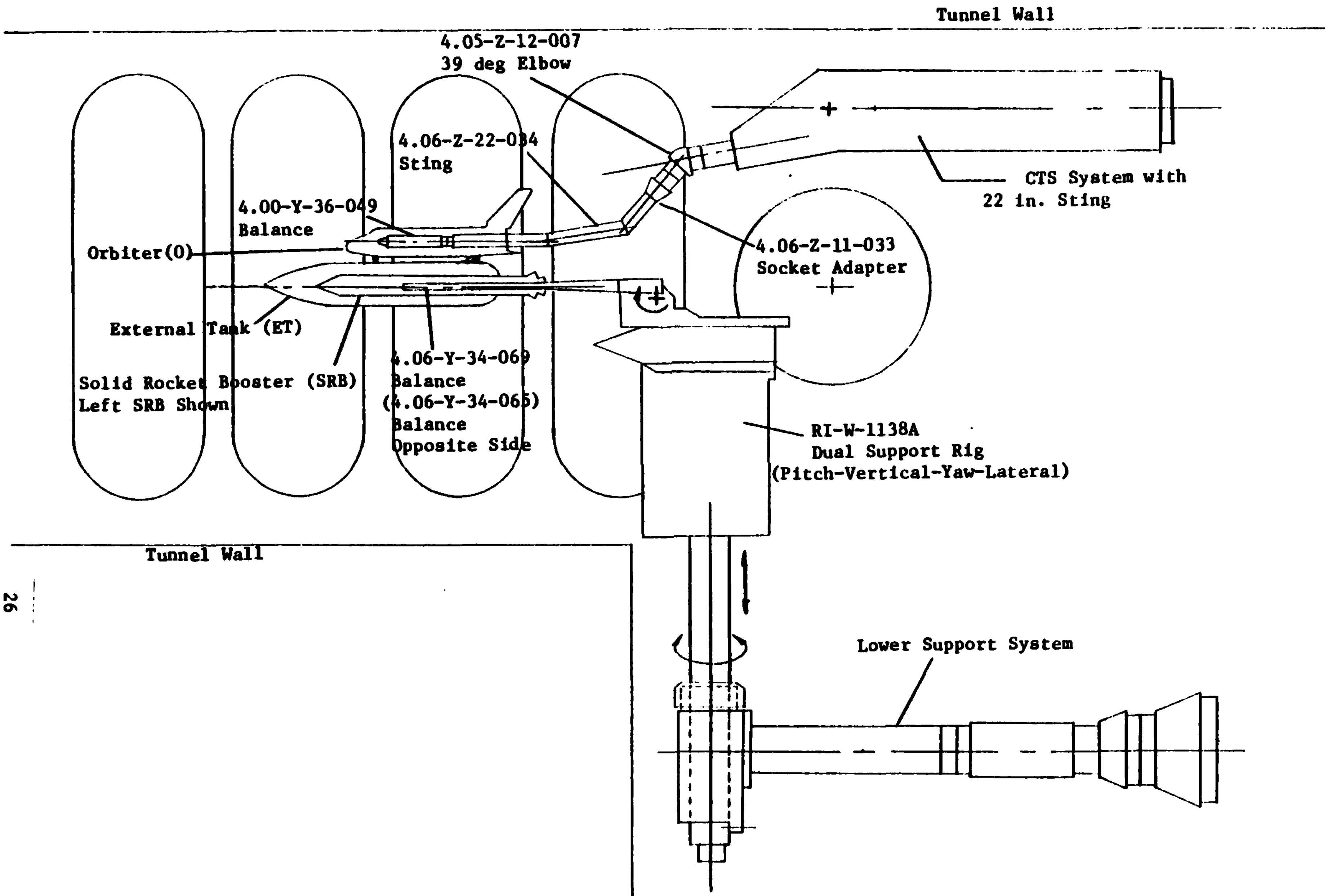


Figure 4. Phase I Test Installation Sketch

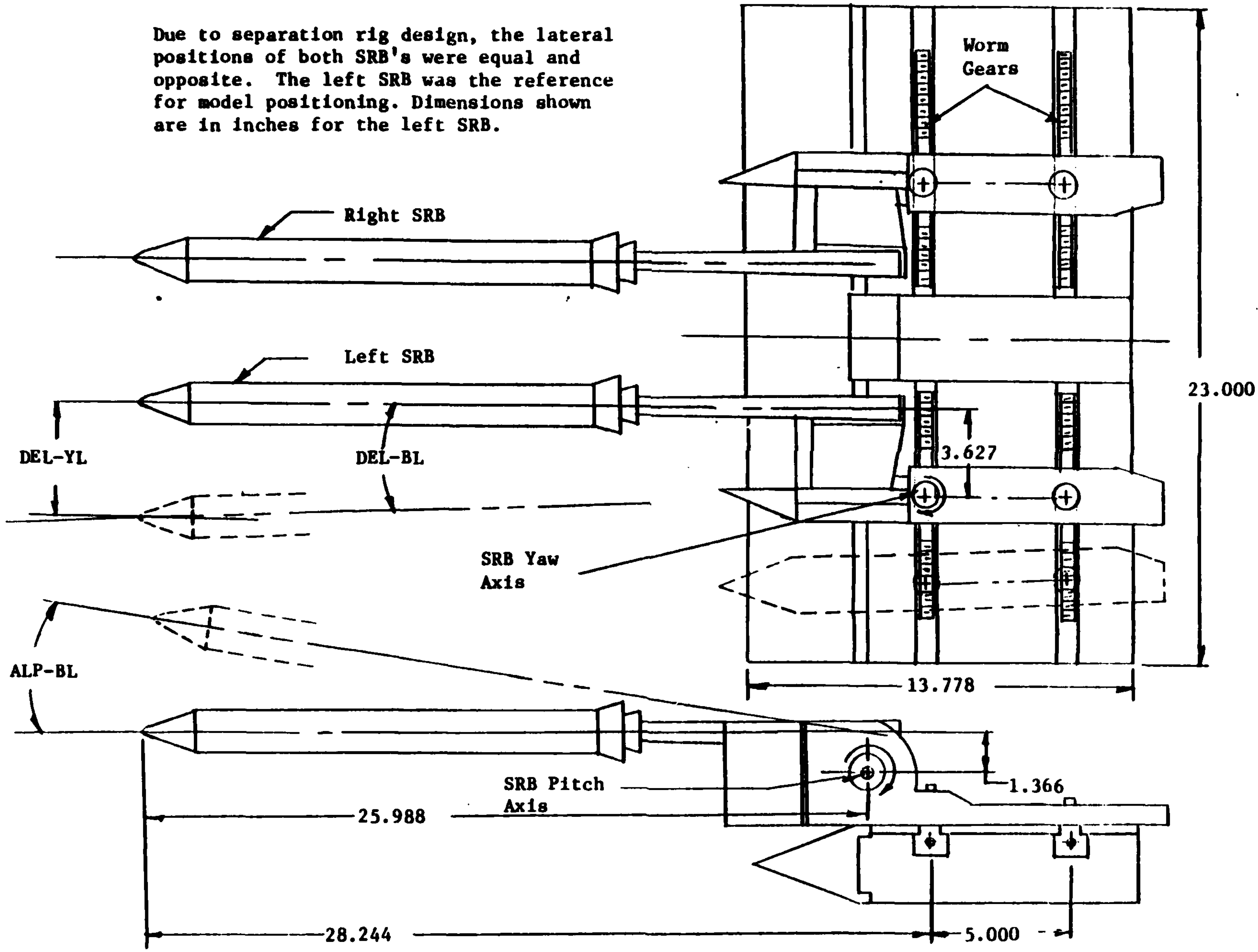


Figure 5. Dual Model Support Mechanism

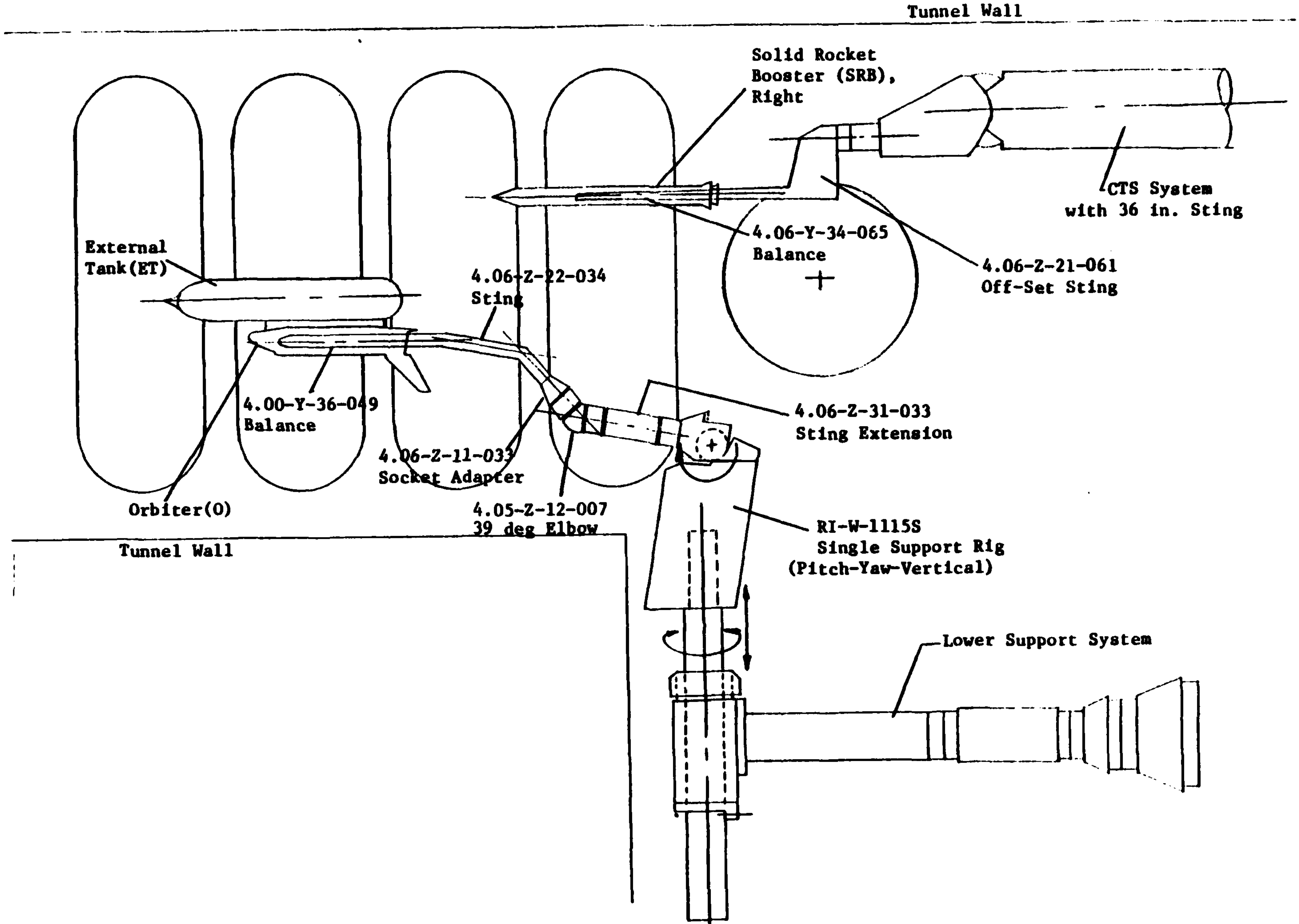


Figure 6. Phase II Test Installation Sketch

Notes:
1. Base pressure tubes (0.093 in. dia.) positioned 0.15 in. aft of locations shown.
2. Aft view of orbiter

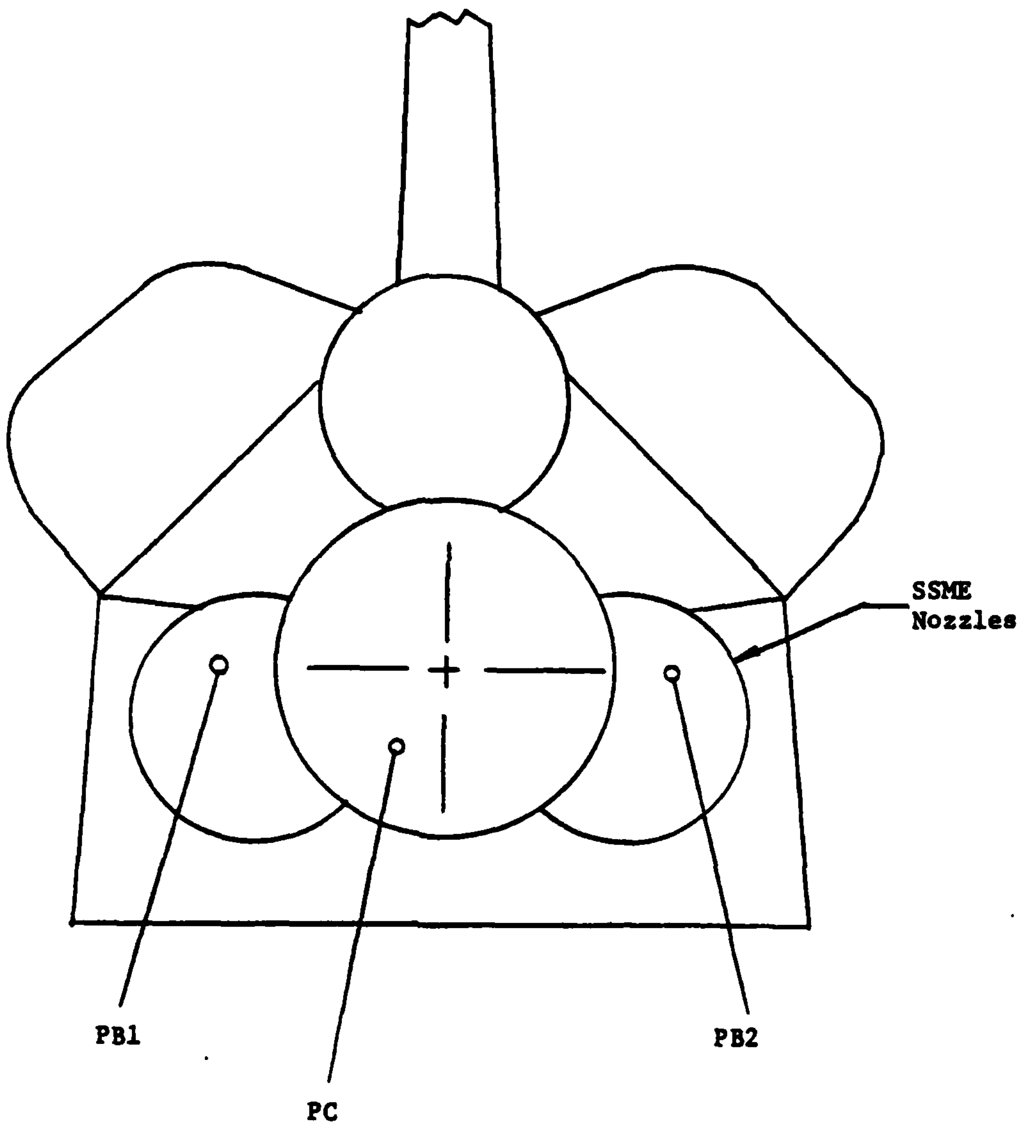


Figure 7. Base Pressure Location

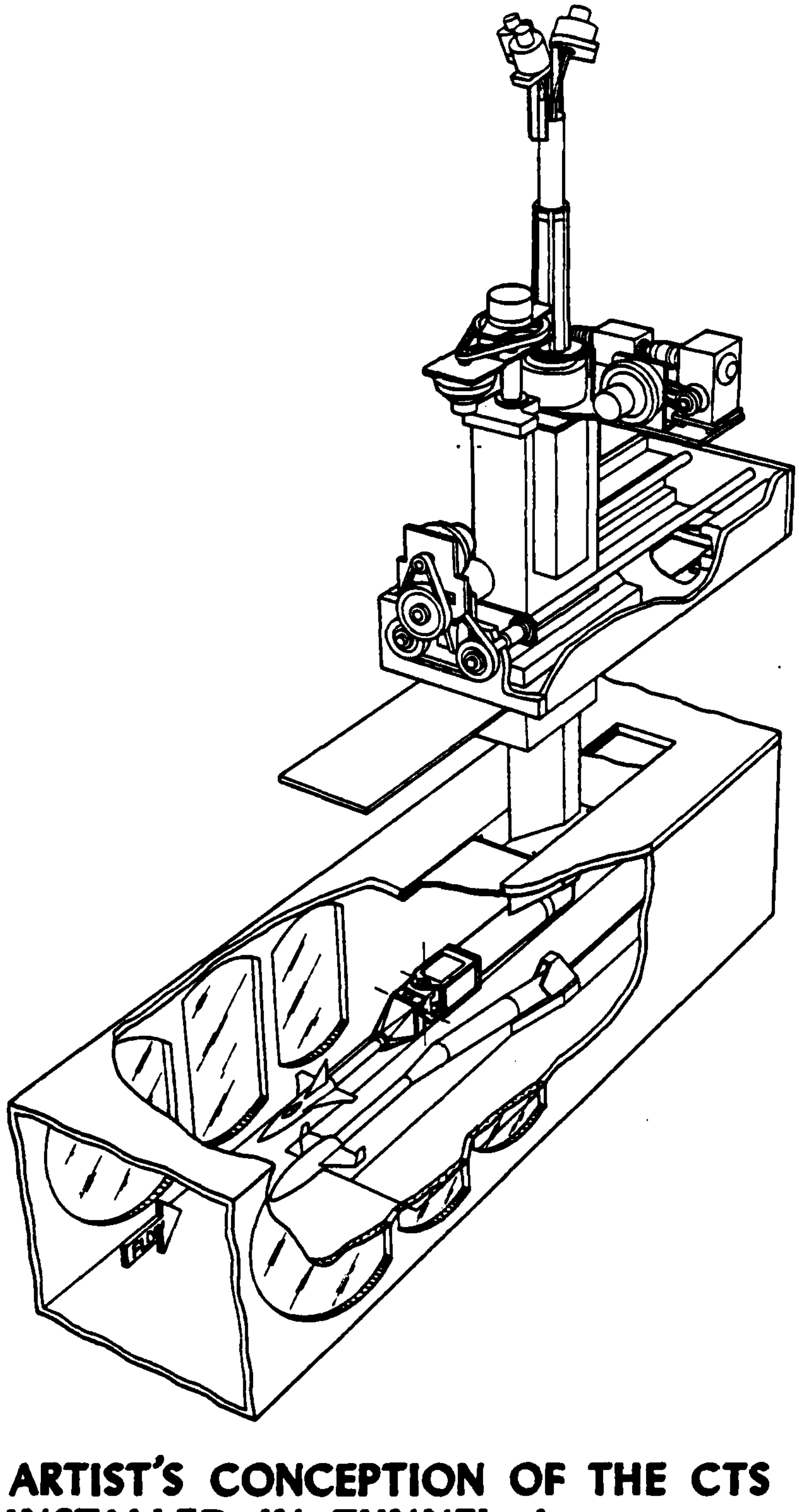
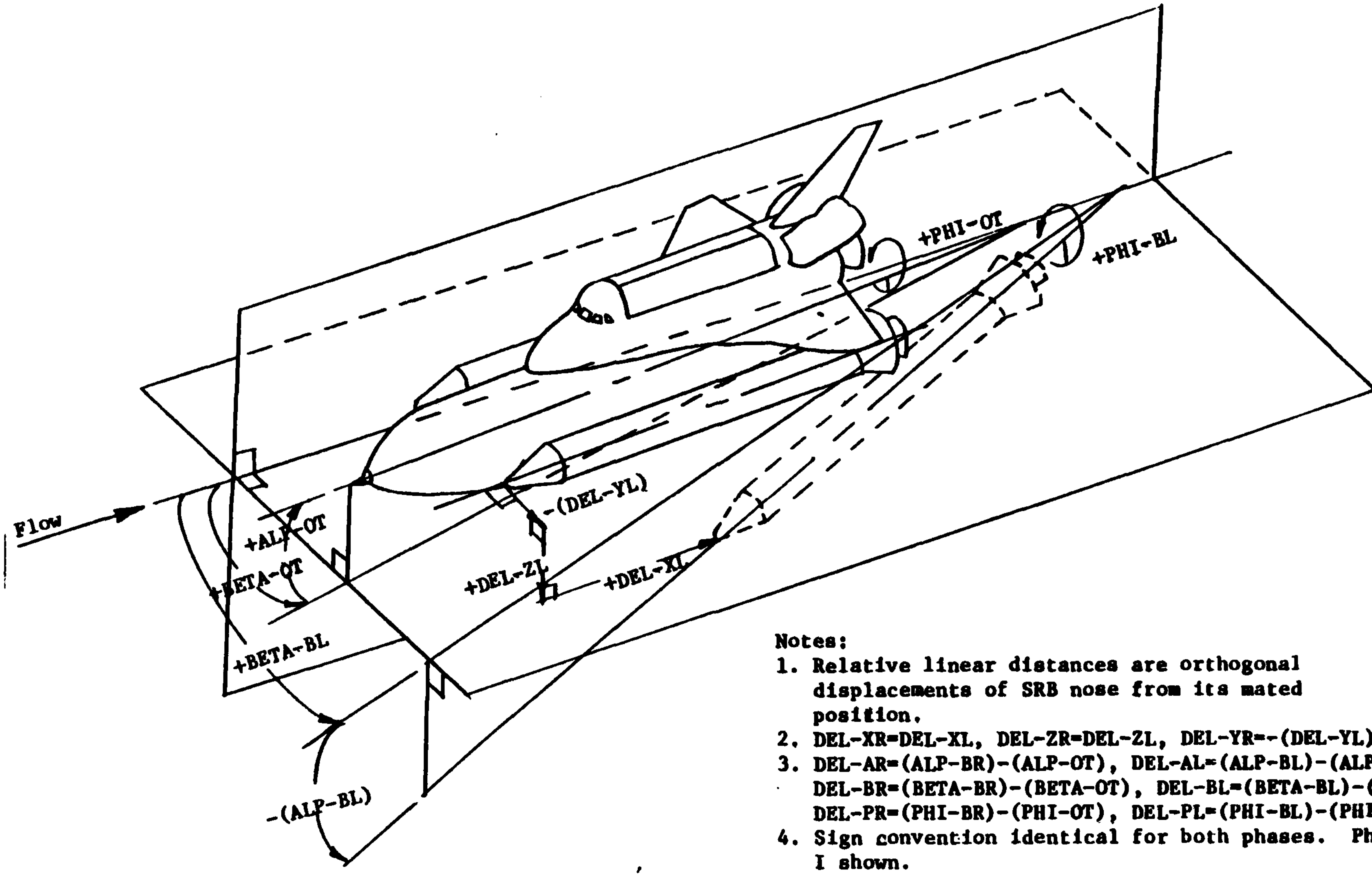
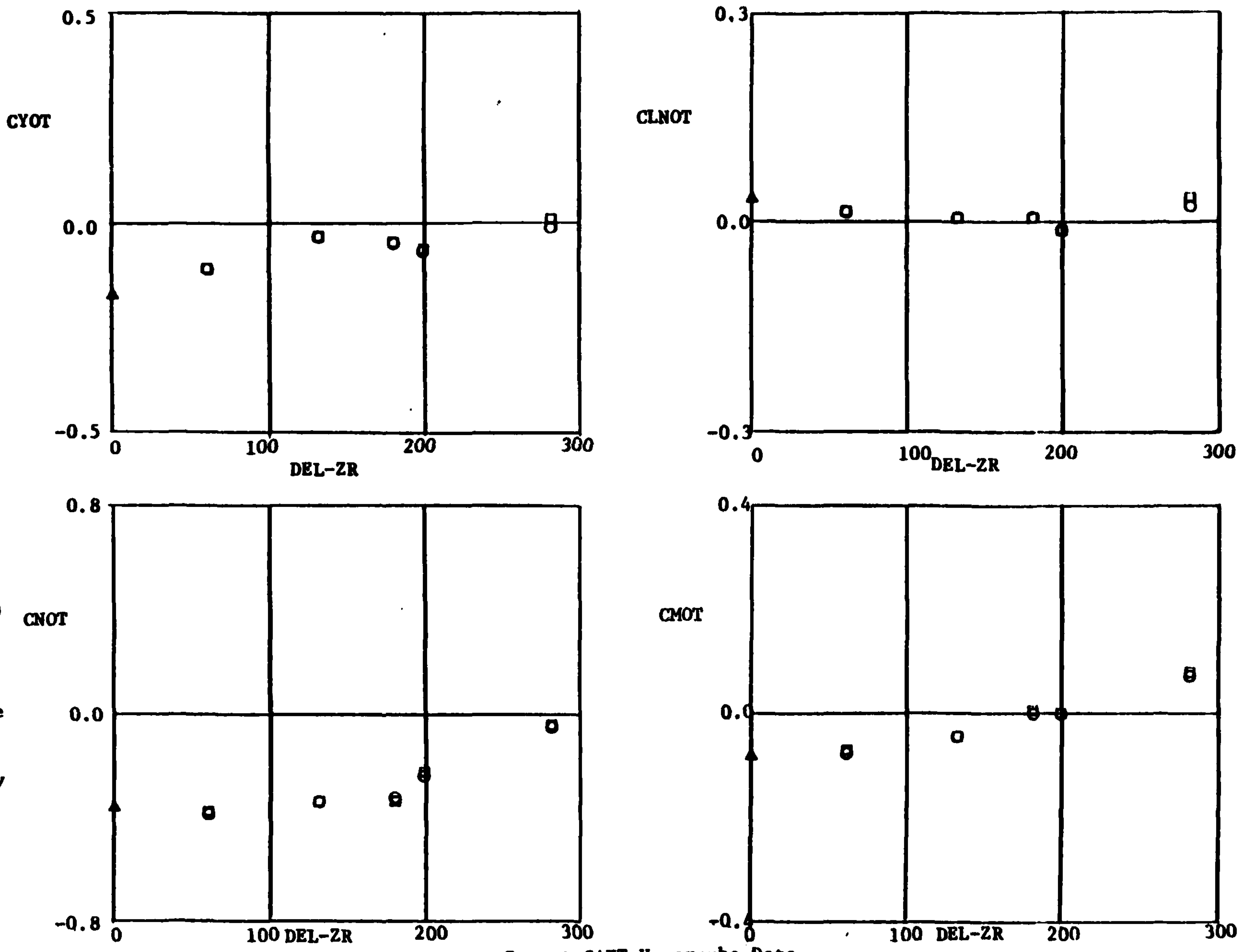


Figure 8. ARTIST'S CONCEPTION OF THE CTS INSTALLED IN TUNNEL A



Notes:
1. Relative linear distances are orthogonal displacements of SRB nose from its mated position.
2. DEL-XR=DEL-XL, DEL-ZR=DEL-ZL, DEL-YR=-(DEL-YL)
3. DEL-AR=(ALP-BR)-(ALP-OT), DEL-AL=(ALP-BL)-(ALP-OT)
   DEL-BR=(BETA-BR)-(BETA-OT), DEL-BL=(BETA-BL)-(BETA-OT)
   DEL-PR=(PHI-BR)-(PHI-OT), DEL-PL=(PHI-BL)-(PHI-OT)
4. Sign convention identical for both phases. Phase I shown.

Figure 9. Sign Convention

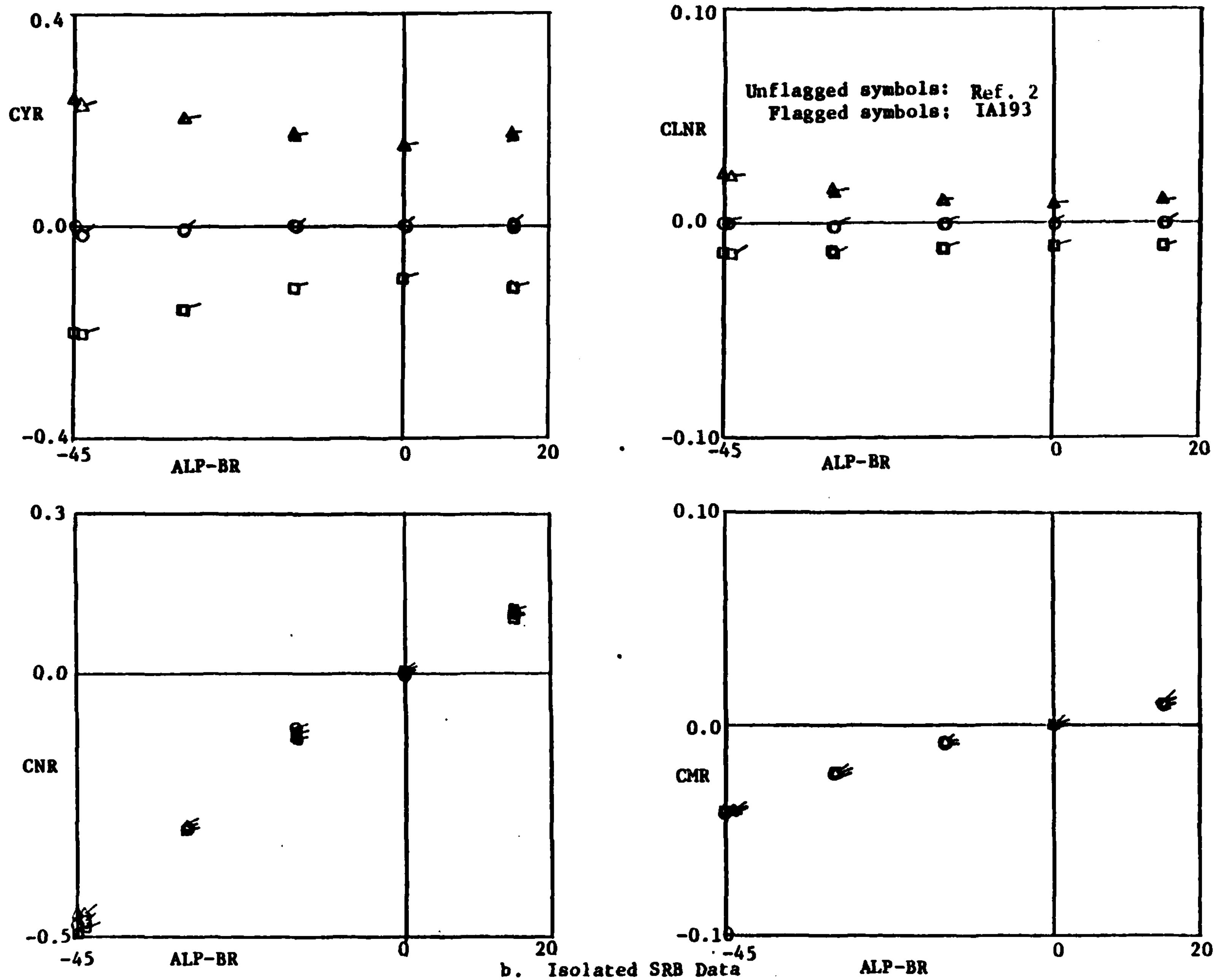


SYM Date
Δ (Mated)
O 3/12/82
□ 3/13/82

Mach=4.5
PCHFR=1500
DEL-XR=200
ALP-OT=-10
BETA-OT=+10
DEL-AR=-7

Symbol size represents estimated uncertainty band.

a. Repeat O+ET Hypercube Data
Figure 10. Verification Plots



SYM BETA-BR
○ 0
△ -20
□ 15

Mach=4.5

Symbol size represents estimated uncertainty band.

b. Isolated SRB Data

Figure 10. Concluded

APPENDIX II

TABLES

TABLE 1. Data Transmittal Summary

The following items were transmitted to the User and Sponsor.

	User	Sponsor
	H. S. Dresser, AC07 Rockwell International 12214 Lakewood Blvd. Downey, CA 90241	M. K. Craig, EX43 NASA/JSC Houston, TX 77058
Item	No. of Copies	No. of Copies
Final Tabulated Data*		
Phase I - 6 volumes	1	1
Phase II - 3 volumes	1	1
Thrust Tares - 1 volume	1	1
Plotted Thrust Tare Data w/curve fits	1	1
Final Data Microfilm	1	
Magnetic Data Tape+ w/format and sample listing	1	1
70 mm Color Schlieren Stills*	2 contact prints 1 dup. negative	1 contact print 1 dup. negative
16mm Color Schlieren Movies	1 work print 1 optical master	1 work print
Flowfield Photographic Log*	1	1

* C. Dill, ED32
NASA/MSFC
Huntsville, AL 35812

Receives same distribution as Sponsor for "*" items

\+ J. E. Vaughn
Chrysler Data Management System
102 Wynn Drive
Huntsville, AL 35805

Receives magnetic tape only

TABLE 2. CTS Motion Capabilities in Tunnel A

MOTION	MAXIMUM[1] TRAVEL LIMITS	MAXIMUM[2] RATE OF TRAVEL
XC	±20 in.	1.2 in.-sec^{-1}
ZC	±15 in.	1.2 in.-sec^{-1}
ETAC[3]	±25 deg	2.7 deg-sec^{-1}
YAWC[3]	±45 deg	10.4 deg-sec^{-1}
ALPHAC	±45 deg	11.7 deg-sec^{-1}
PHICB	±180 deg	20.5 deg-sec^{-1}

NOTES:
1. Travel limits are set up for each test as a function of model location in the tunnel and the test requirements.
2. Rates are continuously variable up to the values shown and can be computer controlled to allow all drives to reach a commanded point simultaneously.
3. YAWC and ETAC combine to provide a lateral motion of ±15 in.

TABLE 3. ESTIMATED UNCERTAINTIES

a. Basic Measurements

Parameter Designation	STEADY-STATE ESTIMATED MEASUREMENT* Precision Index (S) Percent of Reading	Precision Index (S) Unit of Measurement	Precision Index (S) Degree of Freedom	Bias (B) Percent of Reading	Bias (B) Unit of Measurement	Uncertainty $\pm(B + t_{95}S)$ Percent of Reading	Uncertainty $\pm(B + t_{95}S)$ Unit of Measurement	Range	Type of Measuring Device	Type of Recording Device	Method of System Calibration
PO, psia		0.007	>30	0.2		(0.2% PO + 0.014)		15-60	Bell and Howell Force Balance Pressure Transducer	Digital Scanner via Analog-to-Digital (A/D) Converter	In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the Standards Lab
TO, °F		1.0	>30		2.0		4.0	70-300	Chromel®-Alumel® Thermocouple	Digital Scanner via microprocessor based multiplexer via Fluke digital thermometer	TC-verification of NBS conformity Inst-voltage substitution calibration
O+ET:											
Normal Force, lbs		0.060	>30		0.028		0.148	± 65	Six-component strain gage balance (4.00-Y-36-049)	Digital Scanner via A/D converter	Static Loading
Pitching Moment, in.-lbs		0.134	>30		0.044		0.312	± 190			
Side Force, lbs		0.060	>30		0.075		0.195	± 55			
Yawing Moment, in.-lbs		0.079	>30		0.020		0.178	± 160			
Rolling Moment, in.-lbs		0.044	>30		0.018		0.106	± 40			
Axial Force, lbs		0.071	>30		0.017		0.159	0 to 20			
RIGHT SRB:											
Normal Force, lbs		0.059	>30		0.021		0.139	± 60	Four-Component Strain Gage Balance (4.00-Y-34-065)		
Pitching Moment, in.-lbs		0.244	>30		0.040		0.528	± 230			
Side Force, lbs		0.029	>30		0.005		0.063	± 30			
Yawing Moment, in.-lbs		0.149	>30		0.084		0.382	± 115			
LEFT SRB:											
Normal Force, lbs		0.059	>30		0.025		0.143	± 60	Four-component Strain Gage Balance (4.00-Y-34-069)		
Pitching Moment, in.-lbs		0.232	>30		0.118		0.583	± 230			
Side Force, lbs		0.064	>30		0.026		0.154	± 30			
Yawing Moment, in.-lbs		0.260	>30		0.098		0.618	± 115			
XC, in.		0.0023	>30		0.0092		0.0138	±20	Potentiometer		Heidenhein Rotary Encoder ROD 700
ZC, in.		0.0057	>30		0.0026		0.0140	±15			
PHICB, deg		0.0877	>30		0+		0.1754	N/A			
ALPHAC, deg		0.0213	>30		0.0013		0.0439	±45			
YAWC, deg		0.0288	>30		0.0010		0.0586	±45			
ETAC, deg		0.0081	>30		0.0077		0.0239	±25			
YPOT1, YPOT2, in. (separation)		0.004	>30		0.004		0.012	1.550-8.100			Comparison to gage blocks

*Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.

+Assumed to be zero

Note: Balance Load Ranges from Check Calibration

TABLE 3. Continued

a. Concluded

Parameter Designation	STEADY-STATE ESTIMATED MEASUREMENT* Precision Index (S) Percent of Reading	Precision Index (S) Unit of Measurement	Precision Index (S) Degree of Freedom	Bias (B) Percent of Reading	Bias (B) Unit of Measurement	Uncertainty $\pm(B + t_{95}S)$ Percent of Reading	Uncertainty $\pm(B + t_{95}S)$ Unit of Measurement	Range	Type of Measuring Device	Type of Recording Device	Method of System Calibration
PA, psia		0.22	>30		1.5		1.94	0-2000	Setra Variable Capacitance Pressure Transducer	Digital Scanner via A/D Converter	In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the Standards Lab
DEL-P, psid		0.006	>30		0.074		0.086	0-50			
PSL, PSR, psia		0.22	>30		1.5		1.94	0-2000			
PC, PB1, PB2 (Phase I), psia		0.002	>30		0.008		0.012	0-15	Kistler Force Balance Pressure Transducer		
PSWB, PSWT, psia		0.002	>30		0.008		0.012	0-15			
PC, PB1, PB2 (Phase II), psia		0.0015	>30	0.15		(0.15% + 0.003)		0-15	Bell and Howell Variable Capacitance Pressure Transducer		
PCHAL, PCHAR, PCHFL, PCHFR, psia		0.2	>30		0.8		1.2	0-2000	Bell & Howell Force Balance Pressure Transducer		
TA, °F		1.0	>30		2.0		4.0	0-500	Chromel®-Alumel® Thermocouple	Digital Temperature Instrument	TC-verification of NBS conformity Inst-voltage substitution calibration
LTFW, LTAFT, RTFW, RTAFT, °F		1.0	>30		2.0		4.0	0-500	Copper-Constantan® Thermocouple		
TDP, °F		1.0	>30	5.0		(5.0%TDP+2.0)			Panametrics Moisture Monitoring Instrument, Model 2000		Comparison to EG&G dewpoint instrument
Moment Transfer Distances, in.		0.0025	>30		0+		0.0050	--	Precision Height Gage and Micrometers	Manual	Calibration Standards Laboratory

*Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.
+ Assumed to be zero

TABLE 3. Continued

b. Calculated Parameters

Parameter Designation	STEADY-STATE ESTIMATED MEASUREMENT* Precision Index (S) Percent of Reading	Precision Index (S) Unit of Measurement	Degree of Freedom	Bias (B) Percent of Reading	Bias (B) Unit of Measurement	Uncertainty $\pm(B + t_{95}S)$ Percent of Reading	Uncertainty Unit of Measurement	Remarks	Range
MACH		0.011			0+		0.022	Mach 4.5	
		0.009			0+		0.018	Mach 4.0	
P8,psia		0.0011			0.0002		0.0024	Mach 4.5	0.081
		0.0012			0.0000		0.0024	Mach 4.0	0.102
Q8,psia		0.0102			0.0023		0.0227	Mach 4.5	1.151
		0.0086			0.0001		0.0173	Mach 4.0	1.151
RE/ftx10^{-6}		0.0188			0.0342		0.0718	Mach 4.5	1.5
		0.0157			0.0293		0.0607	Mach 4.0	1.3
CNOT		0.0051			0.0013		0.0115	Phase I	±0.5559
CMOT		0.0012			0.0003		0.0027		±0.1359
CYOT		0.0036			0.0008		0.0080		±0.3981
CLNOT		0.0012			0.0003		0.0027		±0.1389
CLLOT		0.0004			0.0001		0.0009		±0.0436
CATOT		0.0026			0.0006		0.0058		0 to 0.2954
CNOT		0.0033			0.0009		0.0075	Phase II	±0.3371
CMOT		0.0009			0.0002		0.0020		±0.0996
CYOT		0.0043			0.0010		0.0096		±0.4842
CLNOT		0.0016			0.0004		0.0036		±0.1748
CLLOT		0.0006			0.0001		0.0013		±0.0585
CATOT		0.0025			0.0006		0.0056		0 to 0.2745
CNTL		0.0105			0.0027		0.0237	Total Loads	±1.1830
CMTL		0.0015			0.0006		0.0036		±0.1685
CYTL		0.0043			0.0017		0.0103		±0.4876
CLNTL		0.0007			0.0005		0.0019		±0.0777
CNL		0.0013			0.0013		0.0039	AERO Loads	±0.1309
CML		0.0003			0.0005		0.0011		±0.0299
CYL		0.0014			0.0015		0.0043		±0.1471
CLNL		0.0004			0.0005		0.0013		±0.0345
CNTR		0.0106			0.0024		0.0236	Total Loads	±1.1860
CMTR		0.0015			0.0003		0.0033		±0.1592
CYTR		0.0045			0.0010		0.0100		±0.4988
CLNTR		0.0008			0.0002		0.0018		±0.0820
CNR		0.0022			0.0006		0.0050	AERO Loads (Phase I)	±0.2014
CMR		0.0006			0.0001		0.0013		±0.0313
CYR		0.0009			0.0002		0.0022		±0.0695
CLNR		0.0004			0.0002		0.0010		±0.0256

*Abernethy, R. B. et al. and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.

+Assumed to be zero

Note: Force and moment coefficient uncertainties given for Mach 4.5 only.

TABLE 3. Concluded

b. *Concluded*

Parameter Designation	STEADY-STATE ESTIMATED MEASUREMENT* Precision Index (S) Percent of Reading	Precision Index (S) Unit of Measurement	Precision Index (S) Degree of Freedom	Bias (B) Percent of Reading	Bias (B) Unit of Measurement	Uncertainty $\pm(B + t_{95}S)$ Percent of Reading	Uncertainty $\pm(B + t_{95}S)$ Unit of Measurement	Remarks	Range
CNR		0.0062			0.0014		0.0138	Phase II (AERO Loads only)	±0.6852
CMR		0.0010			0.0002		0.0022		±0.0952
CYR		0.0031			0.0007		0.0069		±0.3378
CLNR		0.0007			0.0002		0.0016		±0.0755
DEL-XL, DEL-XR		0.7			1.3		2.7	Phase I (Relative CTS Positions)	0 to 200
DEL-ZL, DEL-ZR		3.1			0.4		6.6		0 to 280
DEL-AL, DEL-AR		0.053			0.002		0.108		±10
DEL-XR		1.6			1.4		4.6	Phase II (Relative CTS Positions)	0 to 1700
DEL-YR		4.7			1.8		11.2		0 to 800
DEL-ZR		3.5			2.2		9.2		0 to 1000
DEL-AR		0.045			0.013		0.103		-34 to 0
DEL-BR		0.031			0.006		0.068		-20 to 8
ALP-BL, ALP-BR		0.100			0.020		0.220	Phase I	-17 to 10
BETA-BL, BETA-BR		0.040			0.020		0.100		±10
ALP-OT		0.050			0.020		0.120	Phase II	±10
BETA-OT		0.050			0.020		0.120		±10

*Abernethy, R. B. et al. and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.

Note: Force and moment coefficient uncertainties given for Mach 4.5 only.
Linear position uncertainties in full scale inches. Angular positions are in degrees.

TABLE 4 . Test Summary - Phase I

a. Hypercube[1,2,3,4]

DEL-XR=100

CUBE	CORNER NO.	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
Outer	1	110	150	-7.0	-5.5
	2			-7.0	1.0
	3			0.0	-5.5
	4			0.0	1.0
	5	90	250	-7.0	-4.5
	6			-7.0	1.0
	7			0.0	-4.5
	8			0.0	1.0
	9	50	40	-4.0	-2.5
	10			-4.0	1.0
	11			0.0	-2.5
	12			0.0	1.0
	13	10	60	-4.0	-0.5
	14			-4.0	1.0
	15			0.0	-0.5
	16			0.0	1.0
Inner	1	60	110	-4.0	-1.5
	2			-4.0	0.0
	3			0.0	-1.5
	4			0.0	0.0
	5		70	-4.0	-1.5
	6			-4.0	0.0
	7			0.0	-1.5
	8			0.0	0.0
	9	30	110	-4.0	-1.5
	10			-4.0	0.0
	11			0.0	-1.5
	12			0.0	0.0
	13		70	-4.0	-1.5
	14			-4.0	0.0
	15			0.0	-1.5
	16			0.0	0.0
Center(no E.O.)[5]		40	90	-4.0	-1.0
Center(one E.O.)[5]		80	170	-4.0	-2.0

TABLE 4. Continued

a. Concluded

DEL-XR = 200

CUBE	CORNER NO.	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
Outer	1	150	180	-7.0	-6.5
	2			-7.0	0.5
	3			0.0	-6.5
	4			0.0	0.5
	5	80	280	-7.0	-3.5
	6			-7.0	0.5
	7			0.0	-3.5
	8			0.0	0.5
	9		60	-7.0	-3.5
	10			-7.0	0.5
	11			0.0	-3.5
	12			0.0	0.5
	13	20	90	-7.0	-1.0
	14			-7.0	0.5
	15			0.0	-1.0
	16			0.0	0.5
Inner	1	110	130	-7.0	-2.5
	2			-7.0	-0.5
	3			-4.0	-2.5
	4			-4.0	-0.5
	5		200	-7.0	-2.5
	6			-7.0	-0.5
	7			-4.0	-2.5
	8			-4.0	-0.5
	9	60	130	-7.0	-2.5
	10			-7.0	-0.5
	11			-4.0	-2.5
	12			-4.0	-0.5
	13		200	-7.0	-2.5
	14			-7.0	-0.5
	15			-4.0	-2.5
	16			-4.0	-0.5
Center(no E.O.)[5]		90	160	-4.0	-1.5
Center(one E.O.)[5]		-	-	-	-

TABLE 4. Continued

b. Isolated O+ET[1]

BETA-OT	ALP-OT
-10.0	-10.0 to +10.0 in 2.0 deg increments
-8.0	
-6.0	
-4.0	
-2.0	
0.0	
2.0	
4.0	
6.0	
8.0	
10.0	

c. Asymmetry[1,6]

ALP-OT	BETA-OT	DEL-XR	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
0.0	-0.5	100	60	100	-2.5	-0.5
0.0	-1.0	200	120	190	-5.0	-1.0

ALP-OT	BETA-OT	DEL-XL	DEL-YL	DEL-ZL	DEL-AL	DEL-BL
0.0	-0.5	100	-50	105	-3.0	1.5
0.0	-1.0	200	-90	235	-6.0	3.0

TABLE 4. Continued

d. Trajectory[1,4,7]

TRAJECTORY	ALP-OT	BETA-OT	DEL-XR	DEL-YR	DEL-ZR	DEL-AR	DEL-BR	DEL-PR
Inner cube (nominal)	-3.0	0.0	0	0	0	0.0	0.0	0.0,-3.0
	-2.0		50	20	40	-1.0	-0.5	
	0.0		100	50	100	-3.0	-1.0	
	1.0		150	70	140	-4.0	-1.5	
	2.0		200	90	180	-5.0	-2.0	
Outer Cube (engine out)	-3.0		0	0	0	0.0	0.0	
	-3.0		20	0	0	0.0	0.0	
	-1.0		50	40	100	-2.0	-1.5	
	2.0		100	90	200	-5.0	-3.0	
Close-in	-3.0		0	0	0	0.0	0.0	
	-2.0		50	20	30	-1.0	-1.0	
	-1.0		100	40	60	-2.0	-2.0	
	-1.0		150	60	80	-2.0	-2.5	
	0.0		200	80	100	-3.0	-3.5	

TABLE 4. Concluded

e. Test Summary Notes

1. All matrices executed at Mach 4.5, Re/ft 1.5-million except the trajectory matrix which was accomplished at Mach 4.0, Re/ft 1.3-million.
2. Hypercube matrix testing accomplished at the following O+ET attitudes and BSM chamber pressures:

ALP-OT	BETA-OT	Chamber pressure, psia
0.0	0.0	0(DEL-XR=100 only), 900, 1200, 1500
0.0	10.0	0(DEL-XR=100 only), 900, 1500
10.0	0.0	↓
10.0	10.0	↓
-10.0	0.0	↓
-10.0	0.0	↓
4.0	5.0	↓
-4.0	5.0	↓

At some test points with BSM chamber pressure of 1500 psia, model vibrations were experienced and intermediate chamber pressures (≥1000 psia) were selected. See detailed test run log accompanying FDP.
3. Mated vehicle (DEL-XR=DEL-YR=DEL-ZR=DEL-AR=DEL-BR=DEL-PR=0.0) tested at all conditions specified in Item 2.
4. Position and attitude variables specified for right SRB; left SRB is similar.
5. Center hypercube points: E.O. is space shuttle main engine (SSME) engine out.
6. Asymmetry matrix testing accomplished at BSM chamber pressures of 0, 900, 1200, 1500 psia.
7. Trajectory matrix testing accomplished at BSM chamber pressure of 1200 psia only.

TABLE 5. Test Summary - Phase II

a. Hypercube[1,2,3]

DEL - XR = 100

CUBE	CORNER NO.	ALP-OT	BETA-OT	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
Inner	1	0.0	0.0	60	110	-4.0	-1.5
	2					-4.0	0.0
	3					0.0	-1.5
	4					0.0	0.0
	5				70	-4.0	-1.5
	6					-4.0	0.0
	7					0.0	-1.5
	8					0.0	0.0

TABLE 5. Continued

a. Continued

DEL-XR = 300

CUBE	CORNER NO.	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
Outer	1	260	400	-14.0	-15.0
	2			-14.0	2.0
	3			-6.5	-15.0
	4			-6.5	2.0
	5	160	550	-17.0	-9.0
	6			-17.0	2.0
	7			-9.0	-9.0
	8			-9.0	2.0
	9	130	40	-7.0	-7.0
	10			-7.0	2.0
	11			0.0	-7.0
	12			0.0	2.0
	13	30	150	-9.0	-1.0
	14			-9.0	2.0
	15			-2.0	-1.0
	16			-2.0	2.0
Inner	1	170	280	-9.0	-4.0
	2			-9.0	0.0
	3			-5.0	-4.0
	4			-5.0	0.0
	5		180	-9.0	-4.0
	6			-9.0	0.0
	7			-5.0	-4.0
	8			-5.0	0.0
	9	90	280	-9.0	-4.0
	10			-9.0	0.0
	11			-5.0	-4.0
	12			-5.0	0.0
	13		180	-9.0	-4.0
	14			-9.0	0.0
	15			-5.0	-4.0
	16			-5.0	0.0
Center(no E.O.)[4]		130	230	-7.0	-2.0
Center(one E.O.)[4]		170	400	-10.0	-5.0

TABLE 5. Continued

a. Continued

DEL-XR = 600

CUBE	CORNER NO.	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
Outer	1	510	660	-26.0	-20.0
	2			-26.0	3.0
	3			-7.0	-20.0
	4			-7.0	3.0
	5	250	800	-30.0	-12.0
	6			-30.0	3.0
	7			-9.0	-12.0
	8			-9.0	3.0
	9	220	140	-11.0	-11.0
	10			-11.0	3.0
	11			0.0	-11.0
	12			0.0	3.0
	13	90	280	-15.0	-7.0
	14			-15.0	3.0
	15			-2.0	-7.0
	16			-2.0	3.0
Inner	1	290	480	-15.0	-8.0
	2			-15.0	-1.0
	3			-5.0	-8.0
	4			-5.0	-1.0
	5		300	-15.0	-8.0
	6			-15.0	-1.0
	7			-5.0	-8.0
	8			-5.0	-1.0
	9	140	480	-15.0	-8.0
	10			-15.0	-1.0
	11			-5.0	-8.0
	12			-5.0	-1.0
	13		300	-15.0	-8.0
	14			-15.0	-1.0
	15			-5.0	-8.0
	16			-5.0	-1.0
Center(no E.O.)[4]		220	380	-10.0	-5.0
Center(one E.O.)[4]		350	600	-15.0	-8.0

TABLE 5. Continued

a. Continued

DEL-XR = 1100

CUBE	CORNER NO.	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
Outer	1	700	900	-33.0	-20.0
	2			-33.0	3.0
	3			-13.0	-20.0
	4			-13.0	3.0
	5	370		-33.0	-18.0
	6			-33.0	3.0
	7			-13.0	-18.0
	8			-13.0	3.0
	9		180	-17.0	-18.0
	10			-17.0	3.0
	11			0.0	-18.0
	12			0.0	3.0
	13	100	400	-22.0	-16.0
	14			-22.0	3.0
	15			-4.0	-16.0
	16			-4.0	3.0
Inner	1	450	630	-21.0	-15.0
	2			-21.0	-3.0
	3			-10.0	-15.0
	4			-10.0	-3.0
	5		380	-21.0	-15.0
	6			-21.0	-3.0
	7			-10.0	-15.0
	8			-10.0	-3.0
	9	250	630	-21.0	-15.0
	10			-21.0	-3.0
	11			-10.0	-15.0
	12			-10.0	-3.0
	13		380	-21.0	-15.0
	14			-21.0	-3.0
	15			-10.0	-15.0
	16			-10.0	-3.0
Center(no E.O.)[4]		350	500	-16.0	-9.0
Center(one E.O.)[4]		500	750	-22.0	-11.0

TABLE 5. Continued

a. Concluded

DEL-XR = 1700

CUBE	CORNER NO.	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
Outer	1	800	1000	-34.0	-20.0
	2			-34.0	0.0
	3			-15.0	-20.0
	4			-15.0	0.0
	5		300	-27.0	-20.0
	6			-27.0	0.0
	7			-5.0	-20.0
	8			-5.0	0.0
	9	200	1000	-34.0	-16.0
	10			-34.0	8.0
	11			-15.0	-16.0
	12			-15.0	8.0
	13		300	-27.0	-16.0
	14			-27.0	8.0
	15			-5.0	-16.0
	16			-5.0	8.0
Inner	1	650	800	-30.0	-15.0
	2			-30.0	-5.0
	3			-15.0	-15.0
	4			-15.0	-5.0
	5		500	-30.0	-15.0
	6			-30.0	-5.0
	7			-15.0	-15.0
	8			-15.0	-5.0
	9	350	800	-30.0	-15.0
	10			-30.0	-5.0
	11			-15.0	-15.0
	12			-15.0	-5.0
	13		500	-30.0	-15.0
	14			-30.0	-5.0
	15			-15.0	-15.0
	16			-15.0	-5.0
Center(no E.O.)[4]		500	650	-23.0	-10.0
Center(one E.O.)[4]		500	900	-25.0	-18.0

TABLE 5. Continued

b. Isolated SRB[1]

BETA-BR	ALP-BR
-30.0	-44.0 to +20.0 in 5.0 deg increments
-25.0	
-20.0	
-15.0	
-10.0	
-5.0	
0.0	
5.0	
10.0	
15.0	

TABLE 5. Continued

c. Trajectory[1]

TRAJECTORY	ALP-OT	BETA-OT	DEL-XR	DEL-YR	DEL-ZR	DEL-AR	DEL-BR
Inner cube (nominal)	3.0	0.0	0	0	0	0.0	0.0
			100	50	100	-3.0	-1.0
			150	70	140	-4.0	-1.5
			200	90	180	-5.0	-2.0
			300	140	260	-8.0	-3.0
			450	190	350	-11.0	-5.0
			600	240	430	-13.0	-7.0
			850	280	510	-16.0	-8.0
			1100	320	580	-19.0	-9.0
			1400	370	640	-23.0	-10.0
			1700	410	700	-27.0	-11.0
	7.0	5.0	0	0	0	0.0	0.0
			100	50	100	-3.0	-1.0
			150	70	140	-4.0	-1.5
			200	90	180	-5.0	-2.0
			300	140	260	-8.0	-3.0
			450	190	350	-11.0	-5.0
			600	240	430	-13.0	-7.0
			850	280	510	-16.0	-8.0
			1100	320	580	-19.0	-9.0
			1400	370	640	-23.0	-10.0
			1700	410	700	-27.0	-11.0
Outer cube (engine out)	3.0	0.0	50	40	100	-2.0	-1.5
			100	90	200	-5.0	-3.0
			200	160	280	-9.0	-5.0
			300	220	350	-12.0	-7.0
			450	320	450	-16.0	-9.5
			600	410	550	-20.0	-12.0
			850	480	700	-24.0	-13.0
			1100	550	850	-27.0	-14.0
			1400	640	880	-29.0	-16.0
			1700	730	900	-31.0	-18.0
Close-in	3.0	0.0	100	40	60	-2.0	-2.0
			150	60	80	-2.0	-2.5
			200	80	100	-3.0	-3.5
			300	90	130	-8.0	-2.0
			450	120	180	-11.0	-3.5
			600	150	230	-13.0	-5.0
			850	220	270	-16.0	-6.5
			1100	280	310	-19.0	-8.0
			1400	360	360	-22.0	-9.0
			1700	400	400	-25.0	-10.0

TABLE 5. Concluded

d. Test Summary Notes

1. All matrices executed at Mach 4.5, RE/ft 1.5-million.
   Trajectory matrix also accomplished at Mach 4.0, RE/ft 1.3- million.

2. Hypercube matrix testing accomplished at the following O+ET attitudes (unless otherwise noted):

ALP-OT	BETA-OT	ALP-OT	BETA-OT
0.0	0.0	-10.0	10.0
0.0	10.0	-10.0	-10.0
0.0	-10.0	4.0	5.0
10.0	0.0	4.0	-5.0
10.0	10.0	-4.0	5.0
10.0	-10.0	-4.0	-5.0
-10.0	0.0		

3. Mated vehicle (DEL-XR=DEL-YR=DEL-ZR=DEL-AR=DEL-BR=DEL-PR=0.0) tested at all attitudes specified in Item 2.

4. Center hypercube points: E.O. is space shuttle main engine (SSME) engine out.

TABLE 6. Grid Numbering Scheme for Hypercubes

a. Phase I

Basic Format: xxy-zz.n

where the grid number (xxy),
xx = (ALP-OT, BETA-OT) combination
y = DEL-AR = DEL-AL

the sub-grid number (zz),
zz = (DEL-XR, DEL-ZR, DEL-YR, DEL-BR) combination(s) for each hypercube corner

and n is the data point number in a given Data Run.

EXAMPLE: 107-11.2

ALP-OT = -4.0
BETA-OT = +5.0
DEL-AR = -4.0
] see table below

DEL-XR = 100.0 - see table next page

DEL-YR = 60.0
DEL-BR = 0.0
DEL-ZR = 110.0
] see TABLE 4a

The primary grid classifications are given as follows:

ALP-OT	BETA-OT	DEL-AR	GRID NO.*	ALP-OT	BETA-OT	DEL-AR	GRID NO.*
0.0	0.0	0.0	016	-10.0	0.0	0.0	086
↓	↓	-4.0	017	↓	↓	-4.0	087
		-7.0	018			-7.0	088
0.0	10.0	0.0	026	-10.0	10.0	0.0	096
↓	↓	-4.0	027	↓	↓	-4.0	097
		-7.0	028			-7.0	098
10.0	10.0	0.0	036	-4.0	5.0	0.0	106
↓	↓	-4.0	037	↓	↓	-4.0	107
		-7.0	038			-7.0	108
10.0	0.0	0.0	046	4.0	5.0	0.0	116
↓	↓	-4.0	047	↓	↓	-4.0	117
		-7.0	048			-7.0	118

*Grid numbers xx0 are mated position at each (ALP-OT, BETA-OT) combination.

Note: Grids xx6: DEL-AR = 0.0
xx7: DEL-AR = -4.0
xx8: DEL-AR = -7.0

TABLE 6. Continued

a. Concluded

The sub-grid correlation to hypercube corner is provided by the following:

GRID NO.	SUB-GRID* NO.	DEL-XR	CUBE	CORNER NO.
xx6	01	200.0	OUTER	3
	02			4
	03			7
	04			8
	05			11
	06			12
	07			15
	08			16
	09	100.0		3
	10			4
	11			7
	12			8
	13			11
	14			12
	15			15
	16			16
	17		INNER	7
	17.2			3
	18			8
	18.2			4
	19			15
	19.2			11
	20			16
	20.2			12
xx7	01	200.0		3
	01.2			7
	02			4
	02.2			8
	03			11
	03.2			15
	04			12
	04.2			16

GRID NO.	SUB-GRID* NO.	DEL-XR	CUBE	CORNER NO.
xx7	05	200.0	CENTER	No E.O.
	06	100.0	OUTER	9
	07			10
	08			13
	09			14
	10		INNER	5
	10.2			1
	11			6
	11.2			2
	12			13
	12.2			9
	13			14
	13.2			10
	14		CENTER	No E.O.
	15		CENTER	One E.O.
xx8	01	200.0	OUTER	1
	02			2
	03			5
	04			6
	05			9
	06			10
	07			13
	08			14
	09		INNER	1
	09.2			5
	10			2
	10.2			6
	11			9
	11.2			13
	12			10
	12.2			14
	13	100.0	OUTER	1
	14			2
	15			5
	16			6

*Data point number (n) is equal 1, unless otherwise noted.

TABLE 6. Continued

b. Phase II

Basic Format: xxy-z.nn

where the grid number (xxy),
xx = (ALP-OT, BETA-OT) combination
y = DEL-XR

the sub-grid number (zz),
z = (DEL-ZR, DEL-AR, DEL-YR, DEL-BR) combination(s) for each hypercube corner

and <u>nn</u> is the data point number of the sub-grid.

EXAMPLE: 024-4.01

ALP-OT = 0.0
BETA-OT = +10.0
DEL-XR = 1100.0] see table below

DEL-ZR = 900.0
DEL-AR = -13.0
DEL-YR = 700.0
DEL-BR = 3.0] see TABLE 5a

The primary grid classifications are given as follows:

ALP-OT	BETA-OT	DEL-XR	GRID+ NO.	ALP-OT	BETA-OT	DEL-XR	GRID+ NO.	ALP-OT	BETA-OT	DEL-XR	GRID+ NO.
0.0	0.0	100	011	0.0	-10.0	100	061*	-4.0	5.0	100	101*
		300	012			300	062			300	102
		600	013			600	063			600	103
		1100	014			1100	064			1100	104
		1700	015			1700	065			1700	105
0.0	10.0	100	021*	-10.0	-10.0	100	071*	4.0	5.0	100	111*
		300	022			300	072			300	112
		600	023			600	073			600	113
		1100	024			1100	074			1100	114
		1700	025			1700	075			1700	115
10.0	10.0	100	031*	-10.0	0.0	100	081*	4.0	-5.0	100	121*
		300	032			300	082			300	122
		600	033			600	083			600	123
		1100	034			1100	084			1100	124
		1700	035			1700	085			1700	125
10.0	0.0	100	041*	-10.0	10.0	100	091*	-4.0	-5.0	100	131*
		300	042			300	092			300	132
		600	043			600	093			600	133
		1100	044			1100	094			1100	134
		1700	045			1700	095			1700	135
10.0	-10.0	100	051*								
		300	052								
		600	053								
		1100	054								
		1700	055								

+ Grid numbers xx0 are mated position at each (ALP-OT, BETA-OT) combination.
* Grids not used.

NOTE: Grids xx1:DEL-XR = 100, xx2:DEL-XR = 300, xx3:DEL-XR = 600, xx4:DEL-XR = 1100, xx5:DEL-XR = 1700

TABLE 6. Concluded

b. Concluded

The sub-grid correlation to hypercube corner is provided by the following:

GRID NO.	SUB-GRID NO.	CUBE	CORNER NO.*
011	5.01-5.08	INNER	8-1
xxy	1.01-1.04	OUTER	16-13
	2.01-2.04		12-9
	3.01-3.04		8-5
	4.01-4.04		4-1
	5.01-5.16	INNER	16-1
	6.01	CENTER	No E.Q.
	7.01	CENTER	One E.O.

* Hypercube corner numbers listed are inclusive decreasing sequentially (i.e., 16, 15, 14, 13, ... 3, 2, 1).

APPENDIX III

SAMPLE TABULATED DATA

ARVIN/CALSPAN FIELD SERVICES, INC.
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/MI IA193 TEST
PHASE I PLUME-ON

DATE COMPUTED 16-MAR-82
TIME COMPUTED 05:15:12
DATE RECORDED 16-MAR-82
TIME RECORDED 5:15:11
PROJECT NUMBER V A-1G

PAGE= 1 GRID 108-10

RUN	CODE	MACH	PO	TO	QB	PB	TB	RE/FT	REL	A	REF LENGTHS		
4576	1	4.50	23.47	590.7	1.149	0.081	117.0	0.147E+07	0.158E+07	38.736	12.903	12.903	12.903

CONFIG	DELA	DELMF	DELE	DELR	DELSB	DATA TYPE
O+ET+SRB	0.0	0.0	0.0	0.0	0.0	HYPC

	**** ORBITER-TANK****			**** LEFT SRB ****						**** RIGHT SRB *****					
PN	ALP-OT	BETA-OT	PHI-OT	DEL-XL	DEL-YL	DEL-ZL	DEL-AL	DEL-BL	DEL-PL	DEL-XR	DEL-YR	DEL-ZR	DEL-AR	DEL-BR	DEL-PR
1	-3.98	5.01	0.00	200.23	-108.43	128.69	-6.93	0.40	0.00	200.23	108.15	128.69	-6.93	-0.40	0.00
2	-3.92	5.01	0.00	200.57	-108.40	200.46	-6.99	0.40	0.00	200.57	108.12	200.46	-6.99	-0.40	0.00

***** MASS FLOW *****

PN	PA	DEL-P	TA	MDOTV	PSL	PCHAL	PCHFL	RTL	PSR	PCHAR	PCHFR	RTR	TDP	YPOT1	YPOT2	PSWT/PB	PSWB/PB
1	1168.1	19.8	600.7	1.329	924.1	889.5	889.5	0.661	934.8	894.5	894.5	0.668	-100.0	0.927	0.919	0.875	1.094
2	1176.5	20.0	600.7	1.339	930.8	896.0	896.0	0.665	941.6	901.0	901.0	0.673	-100.0	0.927	0.918	0.862	1.117

***** ORBITER TANK *****

PN	ALP-OT	BETA-OT	PHI-OT	CNOT	CMOT	CYOT	CLNOT	CLLOT	CATOT	PC/PB	PB1/PB	PB2/PB
1	-3.98	5.01	0.00	-0.2020	-0.0305	-0.0967	0.0123	-0.0081	0.1959	2.1397	1.3433	1.6534
2	-3.92	5.01	0.00	-0.1244	-0.0109	-0.1028	0.0094	-0.0069	0.2159	2.0509	1.4155	1.6515

Note: Data types TRAJ (trajectory) and ASYM (asymmetric) have identical format.

a. Phase I - page 1

Sample 1. Tabulated Hypercube Format

ARVIN/CALSPAN FIELD SERVICES, INC.
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI IA193 TEST
PHASE I PLUME-ON

DATE COMPUTED 16-MAR-82
TIME COMPUTED 05:15:18
DATE RECORDED 16-MAR-82
TIME RECORDED 5:15:11
PROJECT NUMBER V A-1G

PAGE= 2 GRID 100-10

RUN	CODE	MACH	PO	TO	QB	PB	TB	RE/FT	REL	A	REF LENGTHS		
4576	1	4.50	23.47	590.7	1.149	0.081	117.0	0.147E+07	0.158E+07	38.736	12.903	12.903	12.903

CONFIG	DELA	DELBF	DELE	DELR	DELSB	DATA TYPE
O+LT+SRB	0.0	0.0	0.0	0.0	0.0	MTPC

*****BODY AXIS (AERO AND THRUST)*****

PN	DEL-XL	DEL-YL	DEL-ZL	ALP-BL	BETA-BL	PHI-BL	CNTL	CMTL	CYTL	CLNTL	LTFW	LTAFT
1	200.23	-100.43	120.69	-10.91	5.41	0.00	-0.6955	-0.0966	-0.2565	-0.0360	84.	105.
2	200.57	-100.40	200.46	-10.91	5.41	0.00	-0.6962	-0.0957	-0.2549	-0.0363	84.	106.

*****BODY AXIS (AERO ONLY)*****

PN	DEL-XL	DEL-YL	DEL-ZL	ALP-BL	BETA-BL	PHI-BL	CNL	CML	CYL	CLNL
1	200.23	-100.43	120.69	-10.91	5.41	0.00	-0.0019	0.0054	0.0024	0.0021
2	200.57	-100.40	200.46	-10.91	5.41	0.00	0.0016	0.0070	0.0046	0.0021

*****BODY AXIS (AERO AND THRUST)*****

PN	DEL-XR	DEL-YR	DEL-ZR	ALP-BR	BETA-BR	PHI-BR	CNTR	CMTR	CYTR	CLNTR	RTFW	RTAFT
1	200.23	100.15	120.69	-10.93	4.58	0.00	-0.6966	-0.0900	0.2440	0.0414	104.	102.
2	200.57	100.12	200.46	-10.93	4.58	0.00	-0.7011	-0.0894	0.2425	0.0414	105.	103.

*****BODY AXIS (AERO ONLY)*****

PN	DEL-XR	DEL-YR	DEL-ZR	ALP-BR	BETA-BR	PHI-BR	CNR	CMR	CYR	CLNR
1	200.23	100.15	120.69	-10.93	4.58	0.00	-0.0293	0.0048	-0.0114	-0.0026
2	200.57	100.12	200.46	-10.93	4.58	0.00	-0.0297	0.0059	-0.0144	-0.0029

Note: Data types TRAJ (trajectory) and ASYM (asymmetric) have identical format.

b. Phase I - page 2

Sample 1. Continued

ARVIN/CALSPAN FIELD SERVICES, INC.
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI TA193 TEST
PHASE II PLUME-OFF

DATE COMPUTED 23-APR-82
TIME COMPUTED 01:55:23
DATE RECORDED 27-MAR-82
TIME RECORDED 2: 9:26
PROJECT NUMBER V A-1G

PAGE= 1. GRID 15- 5

RUN	CODE	MACH	PO	TO	QS	PS	TS	RE/FT	REL	A	REF LENGTHS		
4873	1	4.50	23.62	591.7	1.157	0.082	117.2	0.140E+07	0.159E+07	38.736	12.903	12.903	12.903

CONFIG	DELA	DELBF	DELE	DELR	DELSB	DATA TYPE
O+ET+SRB	0.0	0.0	0.0	0.0	0.0	HYPC

***** ORBITER-TANK*****

PN	ALP-OT	BETA-OT	PHI-OT	CNOT	CMOT	CYOT	CLNOT	CLLOT	CATOT	PC/PS	PB1/PS	PB2/PS	PSWT/PS	PSWB/PS
1	-0.09	-0.00	180.00	-0.0604	0.0303	0.0005	-0.0001	0.0004	0.1866	0.7120	0.2521	0.2440	-0.9775	1.0754
2	-0.09	-0.00	180.00	-0.0598	0.0301	0.0009	-0.0003	0.0005	0.1870	0.7372	0.2522	0.2441	-0.8561	1.0758

***** BODY AXIS (AERO ONLY) *****

PN	DEL-XR	DEL-YR	DEL-ZR	ALP-BR	BETA-BR	PHI-BR	DEL-AR	DEL- BR	DEL-PR	CNR	CMR	CYR	CLNR	RTFW	RTAFT
1	1699.93	648.15	500.07	-30.07	-4.97	180.00	-29.98	-4.97	-0.01	-0.3087	-0.0323	0.0585	0.0113	85.	91.
2	1700.05	649.27	500.21	-30.07	-14.99	180.00	-29.98	-14.99	-0.00	-0.2873	-0.0396	0.1475	0.0297	85.	91.

Note: Data type TRAJ (trajectory) has identical format.

c. Phase II

Sample 1. Concluded

ARVIN/CALSPAN FIELD SERVICES, INC.
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI IA193 TEST
PHASE I PLUME-ON

DATE COMPUTED 21-APR-82
TIME COMPUTED 15:17:05
DATE RECORDED 10-MAR-82
TIME RECORDED 1:55:44
PROJECT NUMBER V A-1G

PAGE= 1 GRID 401-10

RUN	CODE	MACH	PO	TO	QS	PS	TS	RE/FT	REL	A	REF LENGTHS		
3611	2	4.50	23.50	595.7	1.151	0.081	118.0	0.146E+07	0.157E+07	38.736	12.903	12.903	12.903

CONFIG	DELA	DELBF	DELE	DELR	DELSB	DATA TYPE
O+ET	0.0	0.0	0.0	0.0	0.0	ISOL

	**** ORBITER-TANK****			**** LEFT SRB ****						**** RIGHT SRB *****					
PN	ALP-OT	BETA-OT	PHI-OT	DEL-XL	DEL-YL	DEL-ZL	DEL-AL	DEL-BL	DEL-PL	DEL-XR	DEL-YR	DEL-ZR	DEL-AR	DEL-BR	DEL-PR
1	-10.01	-6.01	0.00												
2	-7.98	-6.01	0.00												
3	-5.98	-6.01	0.00												
4	-3.98	-6.01	0.00												
5	-1.98	-6.00	0.00												
6	0.02	-6.01	0.00												
7	2.02	-6.01	0.00												
8	4.02	-6.01	0.00												
9	6.01	-6.01	0.00												
10	8.01	-6.01	0.00												
11	10.02	-6.01	0.00												

Note: Non-essential parameters excluded from tabulation.

***** MASS FLOW *****

PN	PA	DEL-P	TA	MDOTV	PSL	PCHAL	PCHFL	MTL	PSR	PCHAR	PCHFR	MTR	TDP	YPOT1	YPOT2	PSWT/PS	PSWR/PS
1																0.835	1.101
2																0.959	1.114
3																0.921	1.113
4																0.897	1.090
5																0.861	1.115
6																0.799	1.114
7																0.774	1.102
8																0.921	1.089
9																1.021	1.102
10																0.865	1.102
11																0.947	1.114

***** ORBITER TANK *****

PN	ALP-OT	BETA-OT	PHI-OT	CNOT	CMOT	CYOT	CLNOT	CLLOT	CATOT	PC/PS	PB1/PS	PB2/PS
1	-10.01	-6.01	0.00	-0.3116	0.0927	0.2120	-0.0648	0.0226	0.2410	0.2088	0.3070	0.2331
2	-7.98	-6.01	0.00	-0.2657	0.0839	0.2041	-0.0614	0.0210	0.2328	0.3568	0.3071	0.2085
3	-5.98	-6.01	0.00	-0.2152	0.0712	0.1974	-0.0579	0.0206	0.2213	0.4306	0.3070	0.2576
4	-3.98	-6.01	0.00	-0.1610	0.0555	0.1905	-0.0549	0.0208	0.2091	0.3199	0.2210	0.2825
5	-1.98	-6.00	0.00	-0.1097	0.0418	0.1817	-0.0507	0.0199	0.1989	0.2460	0.2827	0.2702
6	0.02	-6.01	0.00	-0.0592	0.0278	0.1756	-0.0475	0.0193	0.1890	0.3568	0.2948	0.2577
7	2.02	-6.01	0.00	-0.0101	0.0146	0.1704	-0.0449	0.0186	0.1813	0.1719	0.2949	0.2701
8	4.02	-6.01	0.00	0.0399	0.0013	0.1663	-0.0434	0.0184	0.1751	0.2704	0.2823	0.2822
9	6.01	-6.01	0.00	0.0897	-0.0118	0.1637	-0.0422	0.0186	0.1689	0.2460	0.3073	0.2762
10	8.01	-6.01	0.00	0.1404	-0.0254	0.1595	-0.0399	0.0187	0.1646	0.4185	0.2579	0.3317
11	10.02	-6.01	0.00	0.1916	-0.0400	0.1542	-0.0366	0.0186	0.1596	0.2090	0.3688	0.2579

a. Phase I - O+ET

Sample 2. Tabulated Isolated Data

ARVIN/CALSPAN FIELD SERVICES, INC.
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI IA193 TEST
PHASE II PLUME-OFF

DATE COMPUTED 23-APR-82
TIME COMPUTED 04:02:24
DATE RECORDED 27-MAR-82
TIME RECORDED 3:39:27
PROJECT NUMBER V A-1G

PAGE= 1 GRID 402- 3

RUN	CODE	MACH	PO	TO	Q8	P8	T8	RE/FT	REL	A	REF LENGTHS		
4955	3	4.50	23.59	591.7	1.155	0.082	117.2	0.148E+07	0.000E+00	38.736	12.903	12.903	12.903

CONFIG	DELA	DELBF	DELE	DELR	DELSB	DATA TYPE
SRB	0.0	0.0	0.0	0.0	0.0	ISOL

***** ORBITER-TANK*****

PN	ALP-OT	BETA-OT	PHI-OT	CNOT	CMOT	CYOT	CLNOT	CLLOT	CATOT	PC/P8	PB1/P8	PB2/P8	PSWT/P8	PSWB/P8
1													0.9249	1.0889
2													0.9492	1.0688
3													0.9248	1.0888
4													0.8865	1.0892
5													0.8889	1.0774
6													0.9131	1.0771
7													0.9128	1.0891
8													0.9012	1.0898
9													0.9006	1.0891
10													0.9005	1.0766
11													0.9246	1.0885
12													0.8881	1.0764
13													0.8648	1.0778
14													0.8884	1.0890

***** BODY AXIS (AERO ONLY) *****

PN	DEL-XR	DEL-YR	DEL-ZR	ALP-BR	BETA-BR	PHI-BR	DEL-AR	DEL- BR	DEL-PR	CNR	CMR	CYR	CLNR	RTFW	RTAFT
1				-43.98	-24.95	180.00				-0.4338	-0.0420	0.2918	0.0270	85.	92.
2				-39.93	-24.97	180.00				-0.3898	-0.0364	0.2843	0.0252	85.	92.
3				-34.92	-24.97	180.00				-0.3347	-0.0298	0.2753	0.0227	85.	92.
4				-29.92	-24.97	180.00				-0.2801	-0.0230	0.2646	0.0207	85.	92.
5				-24.92	-24.97	180.00				-0.2252	-0.0171	0.2521	0.0191	86.	92.
6				-19.92	-24.97	180.00				-0.1736	-0.0127	0.2400	0.0174	86.	92.
7				-14.94	-24.98	180.00				-0.1255	-0.0086	0.2302	0.0165	86.	92.
8				-9.95	-24.98	180.00				-0.0812	-0.0051	0.2230	0.0155	86.	92.
9				-4.95	-24.98	180.00				-0.0395	-0.0020	0.2182	0.0147	86.	92.
10				0.05	-24.99	180.00				0.0000	0.0006	0.2164	0.0143	86.	92.
11				5.07	-24.96	180.00				0.0409	0.0034	0.2182	0.0150	86.	92.
12				10.06	-24.98	180.00				0.0829	0.0061	0.2230	0.0154	87.	92.
13				15.06	-24.97	180.00				0.1283	0.0093	0.2313	0.0164	87.	92.
14				20.07	-24.98	180.00				0.1773	0.0133	0.2410	0.0173	87.	92.

Note: Non-essential parameters excluded from tabulation.

b. Phase II - SRB

Sample 2. Concluded

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ARVIN/CALSPAN FIELD SERVICES, INC.                                    DATE COMPUTED 17-MAR-82
AEDC DIVISION                                                         TIME COMPUTED  07:19:53
VON KARMAN GAS DYNAMICS FACILITY                                      DATE RECORDED 17-MAR-82
ARNOLD AIR FORCE STATION, TENNESSEE                                   TIME RECORDED   7:19:36
NASA/RI 1A193 TEST                                                    PROJECT NUMBER V  A-1G
PHASE I PLUME-ON

PAGE= 3    GRID 302- 1

 RUN  CODE   MACH     PO     TO     QB      PB     TB    RE/FT       REL        A     REF LENGTHS
4755    1    4.50   23.48   590.7   1.150   0.081  117.0 0.147E+07  0.159E+07  38.736  12.903   12.903   12.903

CONFIG       DELA  DELBF DELE  DELR  DELSB      DATA TYPE
U+LT+SRB      0.0   0.0   0.0   0.0   0.0          ASYM
PN      X,IN      Y,IN     Z,IN    ALP-T   BETA-T   PHI-T

 1    210.867  -15.304  236.515   -0.48    -1.00     0.00
```

Note: This page only included with data type ASYM (asymmetric).

Sample 3. Tabulated CTS Position

ARVIN/CALSPAN FIELD SERVICES, INC.
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/MI IA193 TEST
PHASE I PLUME-ON

DATE COMPUTED 16-MAR-82
TIME COMPUTED 00:49:17
DATE RECORDED 16-MAR-82
TIME RECORDED 0:49:20
PROJECT NUMBER V A-1G

PAGE= 1 GRID 401- 1

RUN	CODE	MACH	PO	TO	QB	PB	TB	RE/FT	REL	A	REF LENGTHS		
4507	3	4.50	0.53	529.7	0.026	0.002	104.9	0.389E+05	0.419E+05	38.736	12.903	12.903	12.903

CONFIG	DELA	DELBF	DELE	DELR	DELSB	DATA TYPE
SRB	0.0	0.0	0.0	0.0	0.0	MDOT

*****MASS FLOW CALIBRATION*****

****LEFT SRB****

PN	PHI-BL	PSL	PCHAL	PCHFL	FNJL	MYJL	FYJL	MZJL
1	0.00	516.8	497.5	497.5	-16.466	-31.881	-6.173	-12.047
2	0.00	928.7	894.0	894.0	-29.991	-57.031	-11.158	-21.499
3	0.00	1548.5	1490.5	1490.5	-50.389	-94.871	-18.744	-35.676
4	0.00	933.8	898.9	898.9	-30.175	-57.399	-11.190	-21.589
5	0.00	516.1	496.8	496.8	-16.500	-31.863	-6.168	-11.899

****RIGHT SRB****

PN	PHI-BR	PSR	PCHAR	PCHFR	FNJR	MYJR	FYJR	MZJR
1	0.00	520.6	498.2	498.2	-16.364	-30.471	6.322	14.179
2	0.00	936.4	896.0	896.0	-29.780	-54.475	11.497	25.226
3	0.00	1561.2	1493.9	1493.9	-49.868	-90.447	19.315	42.151
4	0.00	940.7	900.1	900.1	-29.866	-54.847	11.517	25.299
5	0.00	519.4	497.0	497.0	-16.310	-30.460	6.297	14.062

PN	PA	DEL-P	TA	MDOTV	TDP
1	649.2	10.0	526.7	0.750	-100.0
2	1170.3	18.9	539.7	1.373	-100.0
3	1961.3	34.7	566.7	2.348	-100.0
4	1175.4	19.1	553.7	1.365	-100.0
5	647.9	9.9	542.7	0.734	-100.0

Sample 4. Tabulated SRB Thrust Calibration Data

END

FILMED

3-83

DTIC